DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

Research Report 1673-RR

REMOVAL OF NUCLEAR BOMB DEBRIS, STRONTIUM 90-YTTRIUM 90, AND CESIUM 137-BARIUM 137 FROM WATER WITH CORPS OF ENGINEERS MOBILE WATER-TREATING EQUIPMENT

Project 8-75-07-460

23 May 1961

U S Army
Engineer Research And
Development Laboratories

FORT BELVOIR, VIRGINIA

U. S. ARMY ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES
CORPS OF ENGINEERS

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PREFACE

The investigation covered by this report was conducted by the Sanitary Sciences Branch, U. S. Army Engineer Research and Development Laboratories (USAERDL), under authority of Project 8-75-07-460 (currently Task 8M75-05-001-07), "Removal of CBR Contaminants from Water." A copy of the project card is included as Appendix A. The study was made at the Jackass Flats area, Atomic Energy Commission's Nevada Test Site, Mercury, Nevada.

The period covered by this report was 16 September 1959 through 5 November 1959.

The following personnel were responsible for supervision of the test program:

Research Section Chief	Don C. Lindsten
Water Supply Section Chief	Richard J. Gainey
Sanitary Sciences Branch Chief	Richard P. Schmitt
Military Department Chief	Neil K. Dickinson

The field test team responsible for installing the equipment and conducting the experiments was as follows:

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Engineer Technician	Joseph F. Mancuso
Water Supply Specialist	M/Sgt Joseph P. Kennedy
Technician	M/Sgt Harvey Fox
Technician	Frederick W. Wolfes

The project was actively supported by the Office of Civil and Defense Mobilization (OCDM), Battle Creek, Michigan, which aided the test program financially and furnished two observer-participants: Mr. William J. Lacy, Physical Sciences Division, Research, OCDM, and Mr. George T. Goforth, Plans Office, CBR Defense, OCDM.

The Sanitary Sciences Branch, USAERDL, acknowledges with appreciation the support given the project by the Defense Atomic Support Agency (DASA), the Atomic Energy Commission (AEC), the Reynolds Electrical and Engineering Co., Inc. (REECO), and the U. S. Army Medical Service Corps (MSC). Lt Col Converse R. Lewis, Jr., MSC, and 2nd Lt Robert Quillin, MSC, were present during much of the test period and contributed materially to the project.

CONTENTS

SUMMARY

A field study on the removal of radioactive substances from water was conducted by the Sanitary Sciences Branch, U. S. Army Engineer Research and Development Laboratories, in cooperation with the Office of Civil and Defense Mobilization, at the Atomic Energy Commission's Nevada Test Site during 16 September through 5 November 1959. Three water-treating units were evaluated for radioactivity-removal efficiency: The standard Army Mobile Water Purification Unit (1,500 gph); a prototype Mobile Ion Exchange Unit (1,500 gph); and an electrodialysis demineralization unit (30 gph). The contaminants used were: (1) aged nuclear bomb debris from an underground detonation, powdered to 3 microns average particle size; (2) strontium 90-yttrium 90; and (3) cesium 137-barium 137. Well water of approximately 900 ppm total dissolved solids was deliberately contaminated with the radioactive material of choice and then subjected to the decontamination procedures.

Significant results were:

a. Radioactivity associated with silicate soil from an underground detonation is only sparingly soluble in water (0.5 percent in these tests).

b. The standard Army Mobile Water Purification Unit is capable of removing over 99 percent of sparingly soluble nuclear bomb debris from water by the processes of coagulation and diatomite filtration.

c. The standard Army Mobile Water Purification Unit is capable of removing 97 percent of yttrium 90, but only 13 percent of strontium 90, from water contaminated with strontium 90-yttrium 90. However, the cation exchange column of the prototype Mobile Ion Exchange Unit effectively removes most of the strontium 90-yttrium 90 which passes the Mobile Water Purification Unit, for an overall activity removal of over 99.9 percent.

d. The standard Army Mobile Water Purification Unit is capable of removing only 2 percent of cesium 137-barium 137 from water. However, the cation exchange column of the prototype Mobile Ion Exchange Unit effectively removes most of the cesium 137-barium 137 which passes the Mobile Water Purification Unit, for an overall activity removal of over 99.9 percent.

e. The cation exchange column of the prototype Mobile Ion Exchange Unit, when operated on the sodium cycle, is capable of removing 96 percent of strontium 90 and 75 percent of yttrium 90 from water contaminated directly with strontium 90-yttrium 90 and not subjected to prior coagulation and filtration.

f. Electrodialysis is capable of removing over 99.9 percent of cesium 137-barium 137 from brackish water. The decontamination process **parallels** the demineralization process.

g. A beta-gamma survey meter with the probe sheathed and inserted into a tank of the water under test was used effectively in the field for monitoring water for radioactivity. The meter reading is proportional to the concentration of radioactive material in the water.

h. The Army Mobile Water Purification Unit and Mobile Ion Exchange Unit were operated on water contaminated to at least 10^7 picocuries per liter without undue radiation hazard to the operator. No special shielding or remote controls were necessary.

The report concludes that:

a. Standard field water purification equipment employing continuous coagulation and diatomite filtration is capable of removing over 99 percent of insoluble or suspended radioactive contaminants from water.

b. Standard water purification equipment employing continuous coagulation and diatomite filtration followed by a water demineralization process is capable of removing over 99 percent of the insoluble and soluble radioactive contaminants from water.

c. Diatomite filter membranes, ion exchange resins, permselective membranes, and equipment in contact with radioactive liquids and subject to corrosion contain some radioactivity after normal decontamination; and studies after extended periods of operation are necessary to develop better methods of decontamination or to determine field capabilities for operation, repair, and maintenance of this equipment.

REMOVAL OF NUCLEAR BOMB DEBRIS, STRONTIUM 90-YTTRIUM 90, AND CESIUM 137-BARIUM 137 FROM WATER WITH CORPS OF ENGINEERS MOBILE WATER-TREATING EQUIPMENT

I. INTRODUCTION

1. Subject. This report describes a field study having as its primary objective the evaluation of a standard Army Mobile Water Purification Unit (1,500 gph), a prototype Mobile Ion Exchange Unit (1,500 gph), and an electrodialysis demineralizer (30 gph) for removing nuclear bomb debris, strontium 90-yttrium 90, and cesium 137-barium 137 from water. An associated objective was to assess the hazard to personnel operating the water-supply equipment. The study was conducted at the Jackass Flats area of the Atomic Energy Commission's (AEC) Nevada Test Site in the fall of 1959.

2. Background. The U. S. Army Corps of Engineers must have the capability of producing drinking water in bulk quantities to meet the requirements of field armies. Not always can they be selective of water sources. Good water sources might not be accessible, and polluted sources or sources contaminated with radioactive materials must be treated onsite by systems designed to produce potable and palatable drinking water. The purpose of this study was to evaluate field water-treatment procedures for removing radioactive contaminants from a natural water source. Extensive laboratory-type investigations had been conducted previously at the Oak Ridge National Laboratory (ORNL) and the U. S. Army Engineer Research and Development Laboratories (USAERDL), but this was the first time that full-scale military field equipment producing drinking water at rated capacity under simulated field conditions was operated for removal of radioactive contaminants. Although the water-treatment equipment evaluated was designed for the support of military operations, the basic processes of coagulation, filtration, and ion exchange are applicable to, and in many instances conventional to, civilian or municipal installations.

II. INVESTIGATION

3. Equipment. The Mobile Water Purification Unit (1,500 gph) is designed primarily for the clarification and treatment of fresh surface-water supplies. The unit is a complete water purification plant having equipment for coagulation, filtration, and disinfection. This equipment is installed and operated in a $2\frac{1}{2}$-ton, truck-mounted van body. Coagulation is accomplished in a specially designed solids-contact clarifier called an Erdlator. This is a continuous-upflow

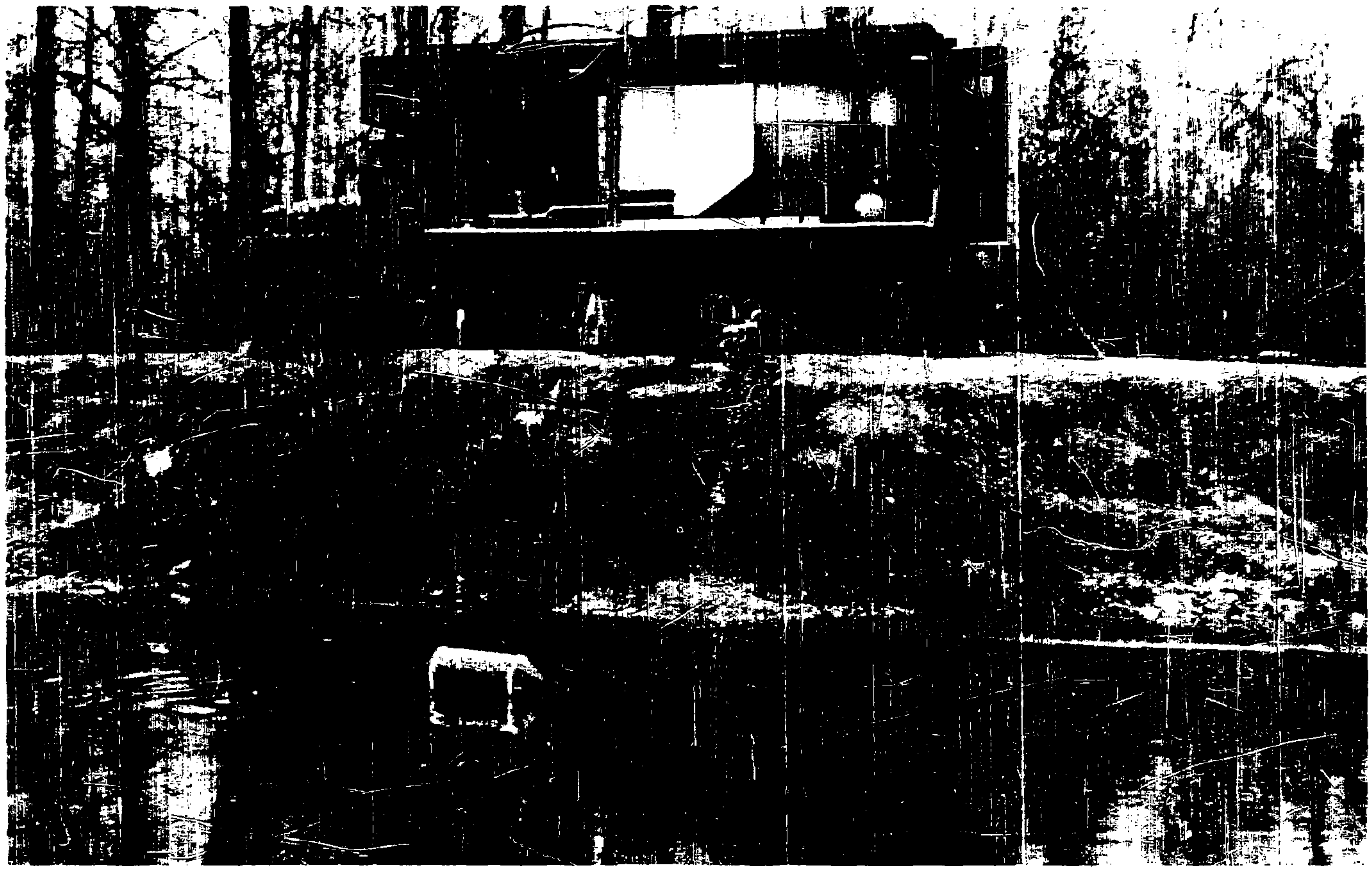

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Fig. 1. Army Mobile Water Purification Unit in use on Accotink Creek, Fort Belvoir, Virginia.

basin having a total retention time of 20 minutes. Following coagulation, the water is filtered through a pressure diatomite filter at $2\frac{1}{2}$ gpm/sq ft rate. All raw water is prechlorinated with calcium hypochlorite to give an available chlorine residual of 1.0 ppm in the final effluent. Figure 1 shows a Mobile Water Purification Unit in use on Accotink Creek, Fort Belvoir, Virginia.

In this study, a sand filter was used in parallel with the standard diatomite filter. This sand filter was 7 ft high with a 1-sq ft cross section. The filter column was made up of a porous supporting plate, a 6-in. layer of gravel, and a 30-in. layer of filter sand with a uniformity coefficient of 1.65 and an effective size of 0.45 mm.

The prototype Mobile Ion Exchange Unit (1,500 gph) is designed primarily for the demineralization of water. The unit is equipped with two separate-bed, regenerative-type ion exchangers. The resins are contained in rubber-lined pressure tanks connected in series. In one tank there is 21 cu ft of a strongly acidic cation resin and in the other, 21 cu ft of a weakly basic anion resin. The service flow through the resin is controlled at a constant rate of $3\frac{1}{2}$ gpm/sq ft of cross-sectional area, and the backwash rate varies from 3 to 4 gpm/sq ft. Regeneration is accomplished at 1.0 gpm/sq ft, and fast rinsing takes place at 3.5 gpm/sq ft. The cation resin is regenerated with a 10-percent solution of commercial hydrochloric acid, using approximately 5 lb of acid per cubic foot of resin. Hydrochloric acid is selected to prevent scaling problems which could occur under field conditions where little or no chemistry can be performed in support of an operation. The anion resin is regenerated with a 4-percent solution of soda ash at a dosage of about 6 lb/cu ft of resin. Soda ash is used as a regenerant because it is already available as a water-supply chemical in the military system, and it also offers certain advantages over other materials relative to storage and ease of handling. On occasion, a mixed-bed column consisting of 3 cu ft of resin was used as a polishing unit following the anion exchanger. Figure 2 shows the Mobile Ion Exchange Unit.

The electrodialysis processing unit studied was a commercially available standard model currently being investigated by USAERDL for the demineralization of brackish-water supplies such as might be obtained from ground water sources in arid or semiarid regions. This unit is rated at 30 gph, reducing brackish water of 3,000 ppm total dissolved solids (tds) to 500 ppm tds. The unit consists essentially of a stack of alternate anion and cation permselective membranes. An electrical potential is imparted across the membrane stack to promote the removal of the soluble ions. Figure 3 shows the electrodialysis demineralization unit. In demineralization studies on the J-11 well water conducted prior to the

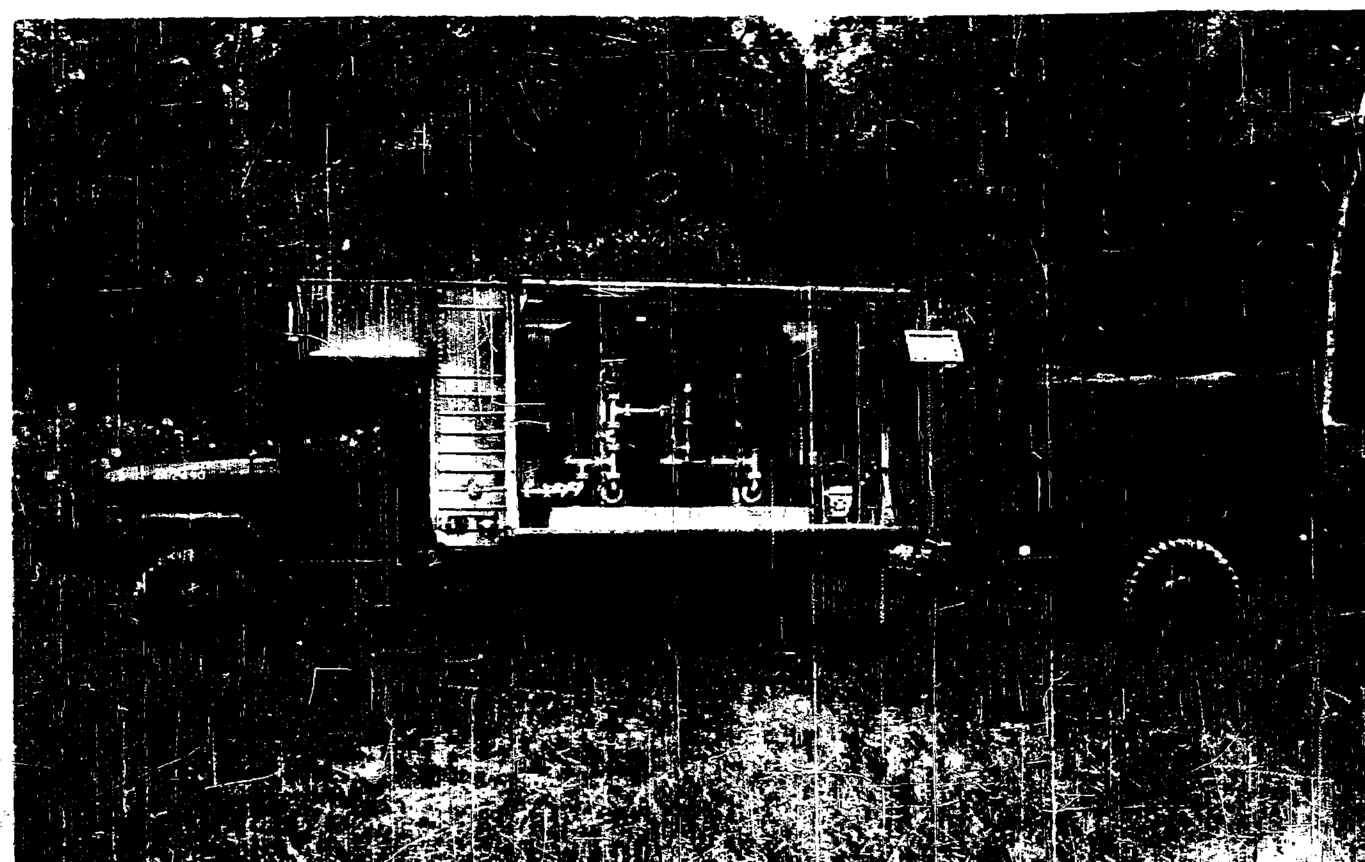

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Fig. 2. Corps of Engineers Prototype Mobile Ion Exchange Unit.

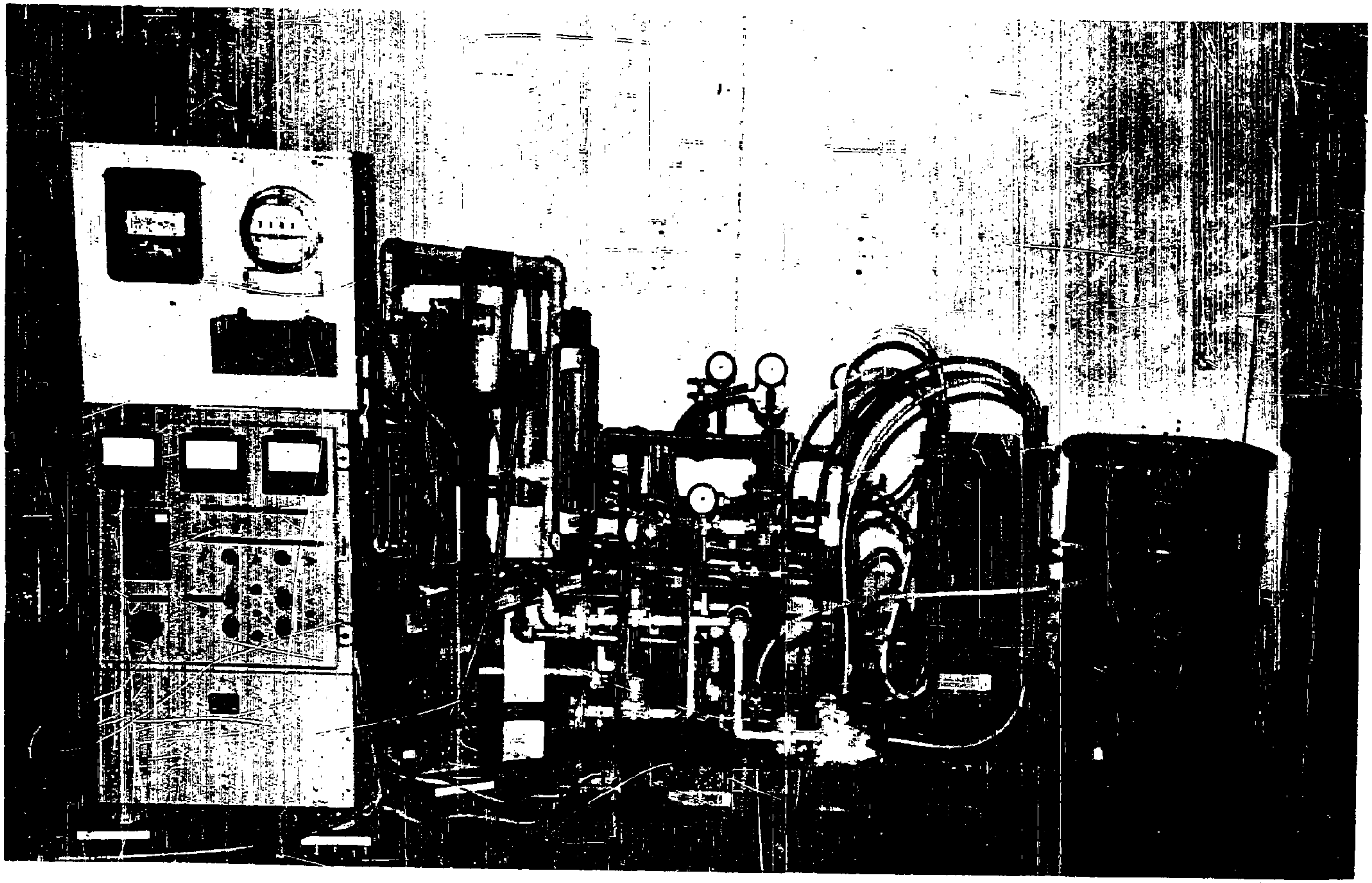

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Fig. 3. Electrodialysis unit (30-gph) for demineralization of saline water.

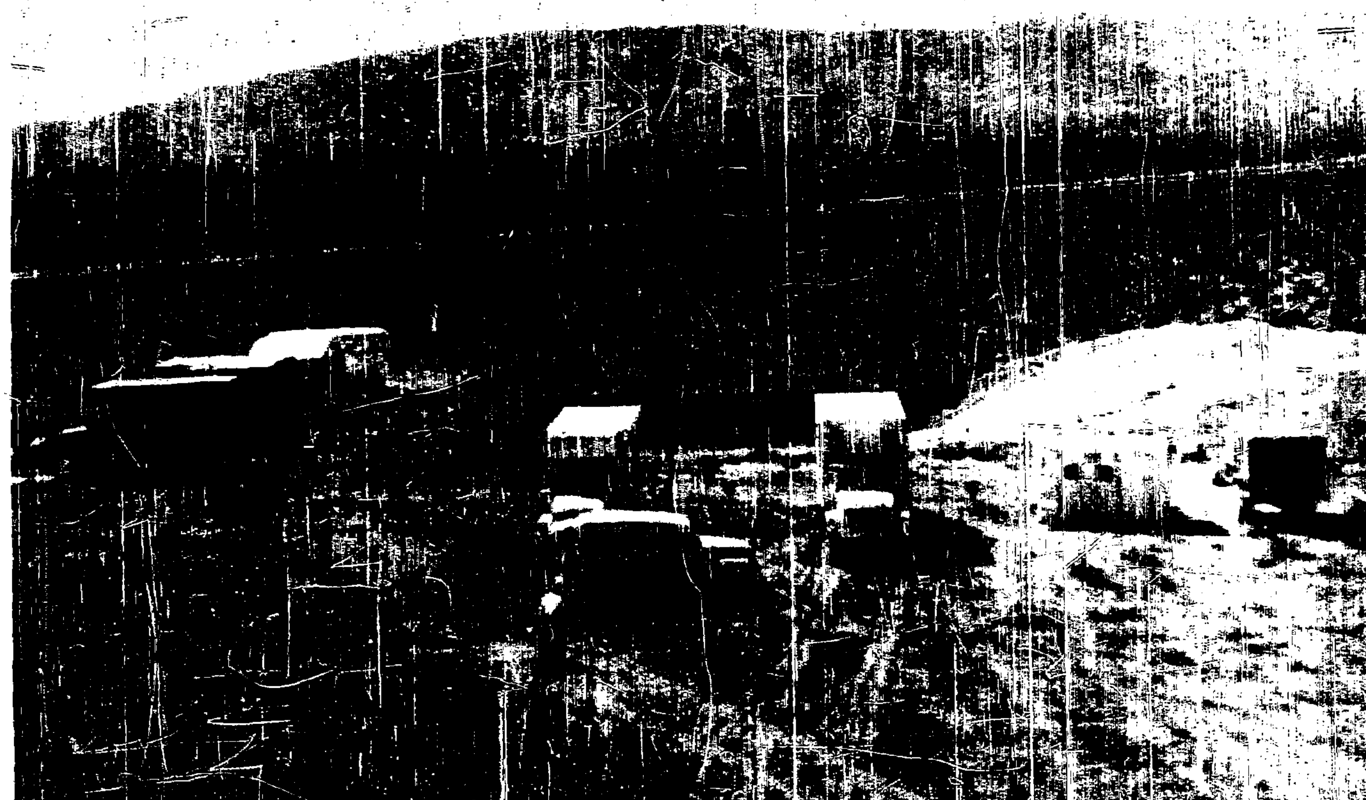

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Fig. 4. Overall view of USAERDL water demineralization and decontamination installation, Jackass Flats, AEC Nevada Test Site.

decontamination studies, the unit produced 55 gal. of water per hour when reducing the 900 ppm tds of uncontaminated water to 300 ppm tds. For the decontamination work, it was necessary to produce a final effluent of 1.5 ppm tds. To do this, the overall production rate was decreased to 7 gph.

4. Procedure. The test program was conducted in the Jackass Flats area of the Atomic Energy Commission's Nevada Test Site. The equipment was installed near a drilled well, 1,330 ft deep, which served as the raw-water source. An overall view of the test area is shown in Fig. 4. An equipment layout diagram is shown in Fig. 5. An analysis of the water from the well is shown in Appendix B, Exhibit 1.

The following radioactive contaminants were used:

a. Radioactive bomb debris.

b. Strontium 90-yttrium 90.

c. Cesium 137-barium 137.

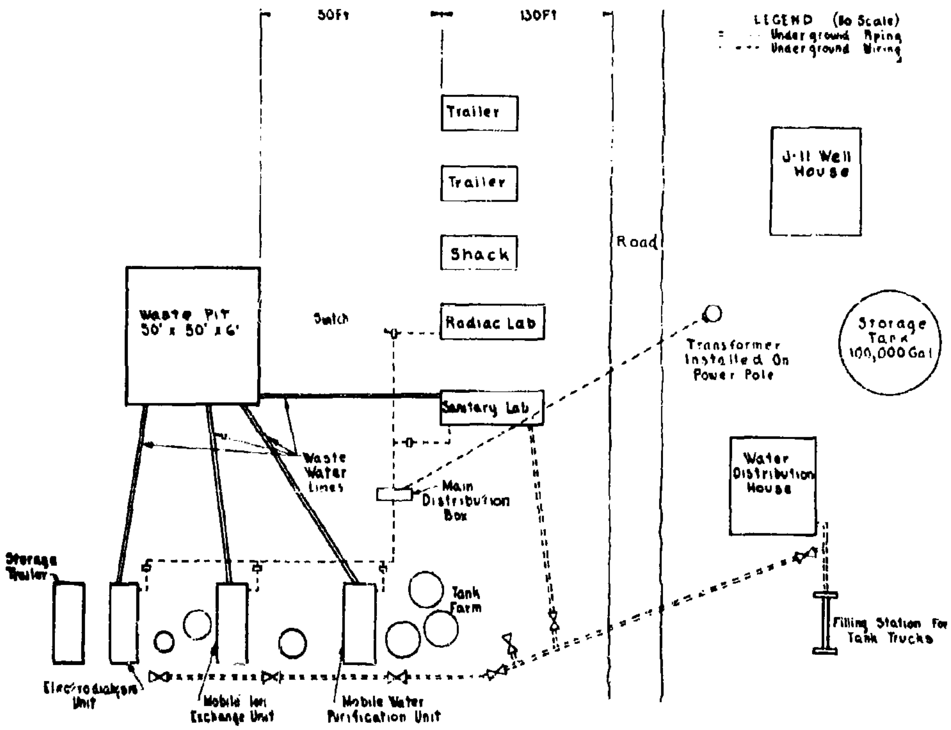

Fig. 5. General layout of USAERDL water demineralization and decontamination installation, Jackass Flats, AEC Nevada Test Site.

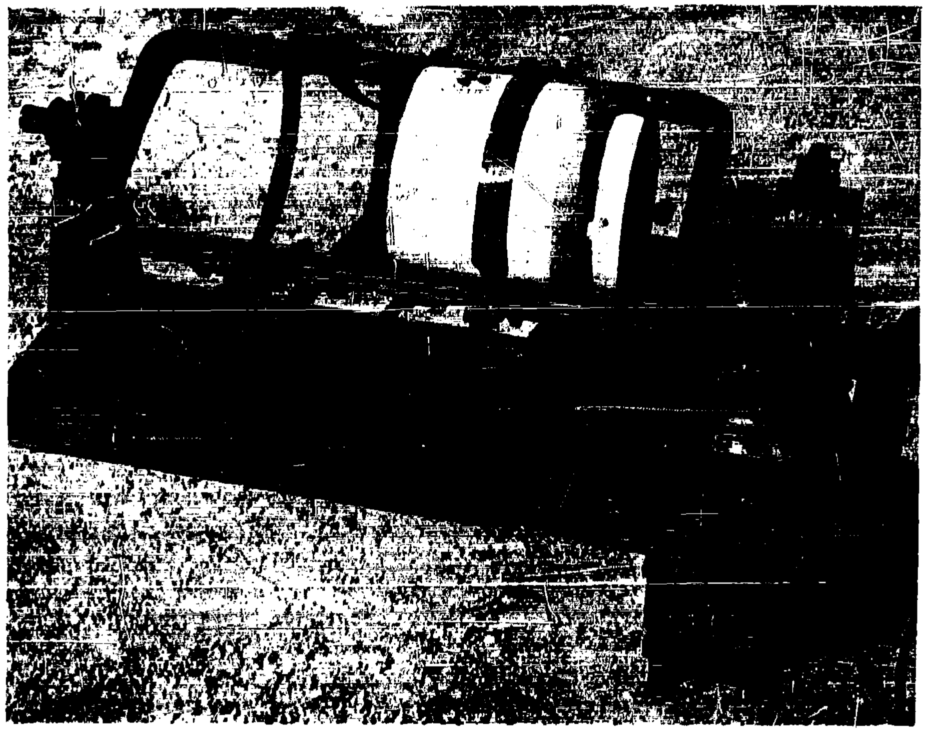

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Fig. 6. Ball mill used to grind coarse radioactive bomb debris to a 3-micron-size powder.

The radioactive bomb debris was approximately 1 year old and was obtained from an underground nuclear detonation. To convert the material to a more usable state, it was ground to a fine powder in a ball mill for 30 hours. After this time, analysis with a subsieve sizer showed the average particle size of the powder to be 3 microns. The powder was analyzed radiochemically. Results were as shown in Appendix B, Exhibit 2. Figure 6 shows the ball mill used to grind the radioactive debris. For one run, the pulverized bomb debris was fused with sodium hydroxide in an effort to disrupt the silicate structure and allow more of the radioactivity to go into solution when slurried with water. The fusion was conducted in an iron pot over a butane burner, using 5 lb of sodium hydroxide for each pound of debris. The fusion mixture was "boiled" for 25 minutes and then neutralized with hydrochloric acid. The resulting slurry was used as the water contaminant.

Strontium 90-yttrium 90 and cesium 137-barium 137 were received from ORNL as chlorides in hydrochloric acid. The radioisotopes were diluted onsite for use as contaminants.

Six test runs were made, and for each run contaminated feed water was prepared by adding the desired amount of powdered bomb debris or soluble radioisotope to well water in a 3,000-gal. nylon-rubber tank. The water was mixed thoroughly with a canoe paddle and also by recirculation with an electrically driven pump. Recirculation was maintained throughout each test run to insure a uniform feed water. Several tanks of water were prepared for each run.

The applied water to the Mobile Ion Exchange Unit is the effluent from the Mobile Water Purification Unit. The dissolved mineral content was changed only slightly from the original raw-water analysis after treatment in the Mobile Water Purification Unit. The significant change was in the clarity of the applied water which averaged approximately 0.1 turbidity unit as an effluent from the Mobile Water Purification Unit and as an influent to the Mobile Ion Exchange Unit. The length of each test run was determined by the operating capacities of the ion exchange resins or when the final effluent conductivity reading indicated a total dissolved solids content of 1 grain per gallon. Operating data for a typical cycle of the Mobile Ion Exchange Unit are shown in Appendix B, Exhibit 3.

During the course of each run, water samples for analyses were taken at regular intervals from predetermined sampling points. Chemical analyses were made in a mobile chemical laboratory, and radiological analyses were made in a mobile radiac laboratory (Fig. 7).

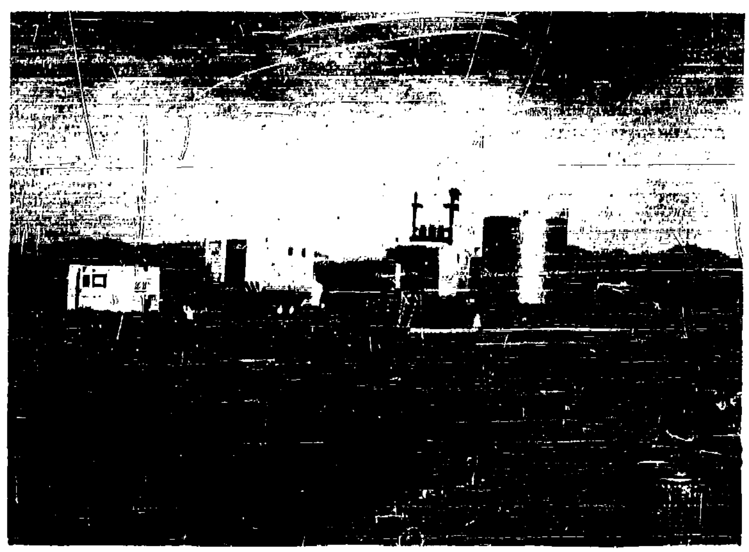

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Fig. 7. View showing mobile radiac laboratory (left) and mobile chemical laboratory (right). Waste effluent pit in foreground.

Most measurements of radioactivity in water were made in order to differentiate between soluble and particulate activity. This was accomplished with the aid of a membrane filter device. The total activity was determined by pipetting an appropriate volume of water (1 to 5 ml) on to an aluminum planchet, drying under an infrared lamp, and counting in an end-window Geiger-Müller beta counter. Soluble activity was determined by measuring the activity of the filtrate passing through a membrane filter of 0.45-micron pore size.

When strontium 90-yttrium 90 was used as the contaminant, the absorber counting technique was used to determine the separate activities. The activity of a given sample was measured with and without an aluminum absorber thick enough to shield out all of the strontium 90 emanations (176 mg/cm^2). The fraction of yttrium activity absorbed was determined by the use of standard strontium 90-yttrium 90 in secular equilibrium. A correction factor for the yttrium 90 activity absorbed was calculated. To determine strontium 90 activity, the corrected yttrium 90 activity value was subtracted from the total activity obtained without the absorber.

All values for the concentration of radioactive materials in water have been expressed in picocuries in accordance with the recent adoption by the National Bureau of Standards of the term "pico" in place of "micro micro."

In addition to the decontamination efficiency of the water purification equipment, information was obtained on the radiation hazard to operating personnel. This information was essential to assess the need for shielding or remote-control operation. During each run, film badges and pocket dosimeters were attached to various components of the equipment to determine the cumulative radiation dose at that point during a given run. Figure 8 is a side view of the Mobile Water Purification Unit with film badges and pocket dosimeters installed. Figure 9 is a sketch of the diatomite filter, sludge concentrator, and Erdlator showing exact location of film badge attachment. Figure 10 is a sketch of the cation, anion, and mixed-bed exchange columns showing the location of the film badges and dosimeters in the Mobile Ion Exchange Unit. Measurements were also taken of the field radiation intensity in the vicinity of the different units during the course of each run.

During most of the runs, a field method of water monitoring was evaluated. According to this method, the probe of a beta-gamma survey meter is covered with a rubber sheath, such as the finger of a surgeon's glove, and is immersed in a tank of the water being monitored. Most of the extraneous area radiation is shielded out, and the meter reading in milliroentgens per hour (mr/hr) is proportional to the number of picocuries per liter of radioactive material in the water.

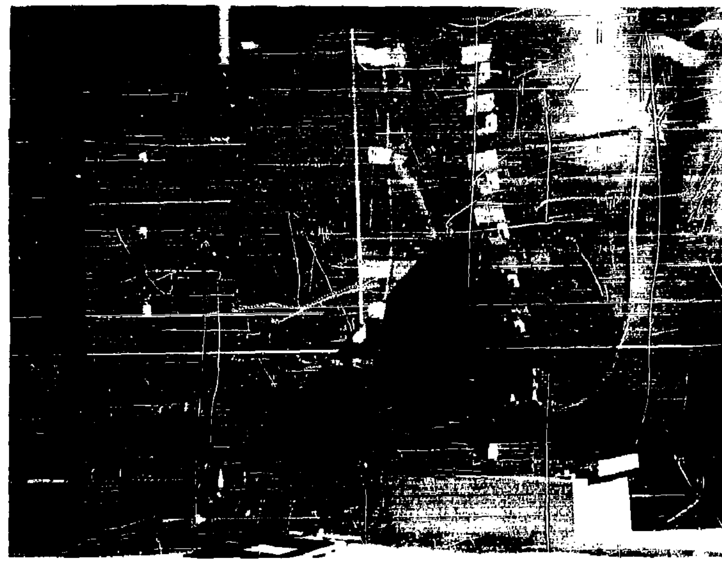

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Fig. 8. Side view of Mobile Water Purification Unit showing Erdlator and sludge concentrator with film badges and pocket dosimeters taped in place for cumulative dosimetry measurements.

Because of the proximity of the test site to the J-11 well, the factor of area contamination was given careful consideration. A waste pit was excavated. This pit received all process water from the Mobile Water Purification Unit and Mobile Ion Exchange Unit, plus sludge from the Erdlator and backwash from the diatomite filter. Ion exchange regeneration fluids from runs using strontium 90-yttrium 90, as well as the cation resin itself upon completion of the studies, were directed into a 1,500-gal. tank. The water was allowed to evaporate, and the tank and its residue were transferred to a waste burial pit on Frenchman Flat.

To minimize the amount of personnel exposure to radiation, strict monitoring procedures were exercised, highly radioactive soil and solutions were handled quickly, and personnel wore protective clothing and used respirators. Film badges were worn at all times.

The detailed procedure for each of the six runs is given in Appendix C (Exhibits 1 through 6).

At the conclusion of all work, the equipment was subjected to decontamination procedures. The Mobile Water Purification Unit was given the principal attention. A 0.8-percent solution of hydrochloric acid was recirculated through the unit for 2½ hours. The

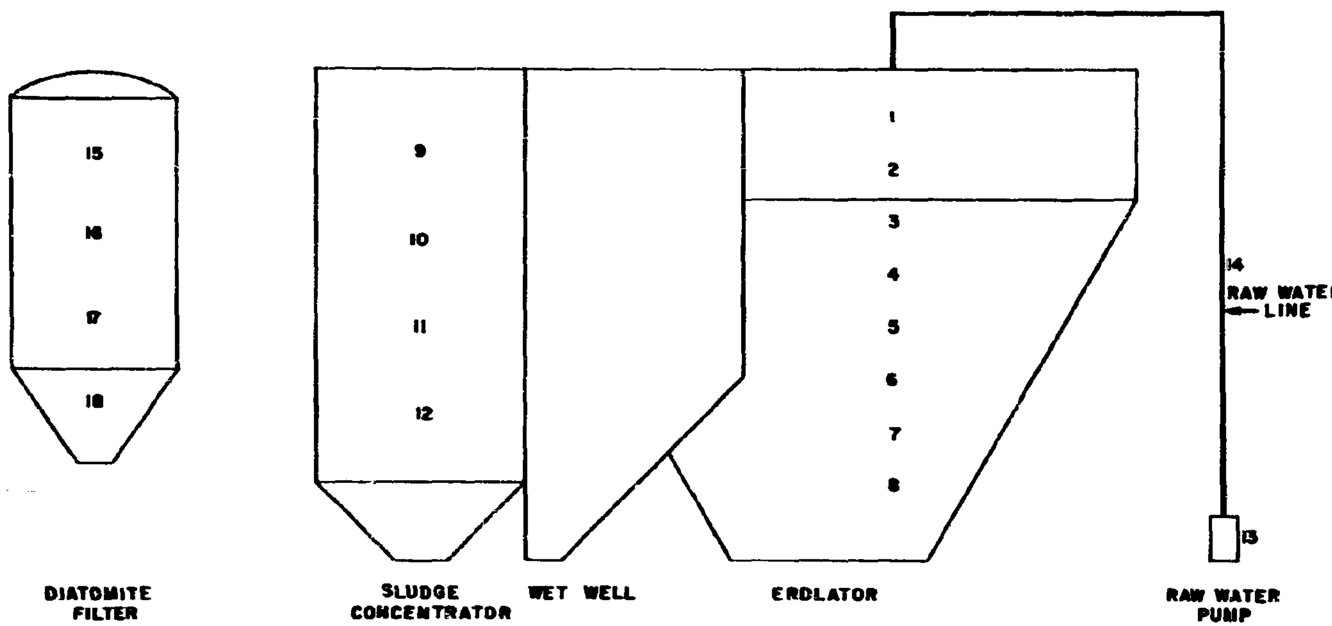

Fig. 9. Sketch of diatomite filter, sludge concentrator, and Erdlator showing film badge locations for dosimetry measurements.

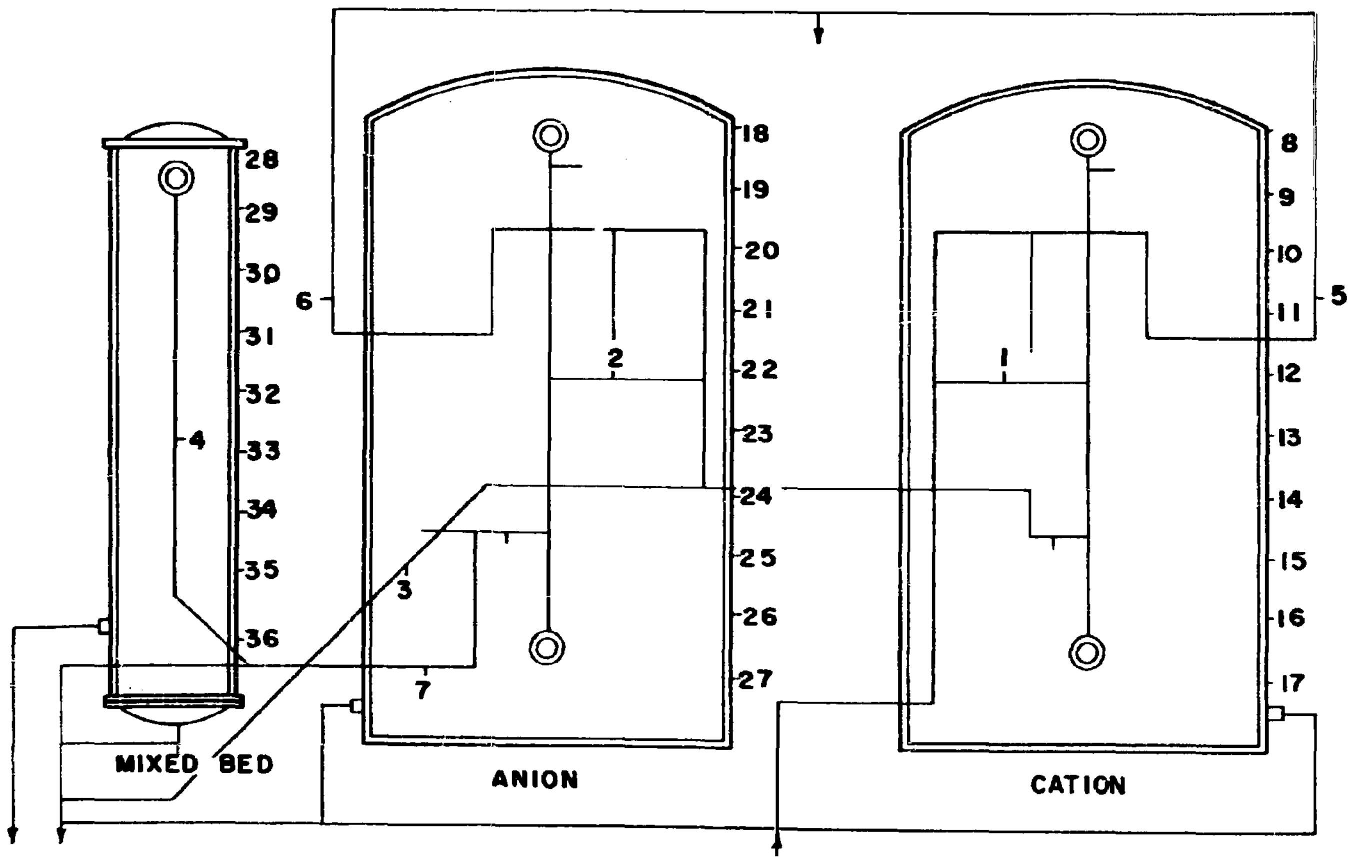

Fig. 10. Sketch of cation, anion, and mixed-bed exchange columns showing film badge locations for dosimetry measurements.

unit was then rinsed with fresh water and given a second flush with a 1.1-percent solution of hydrochloric acid for 2½ hours. The unit was then rerinsed and sent to the AEC-operated decontamination station for steam cleaning, a detergent flush, and a final fresh-water rinse.

The Mobile Ion Exchange Unit was flushed for 2¼ hours with a 1.6-percent solution of hydrochloric acid, rinsed with fresh water, flushed with a 0.8-percent solution of hydrochloric acid for 1 hour, and given a final fresh-water rinse.

The electrodialysis unit was flushed for 4 hours with a 0.1-percent solution of citric acid, followed by a 4-hour rinse with fresh water.

The treatments described above reduced radioactive contamination of the equipment to an insignificant level. Permission was obtained to remove the equipment from the test site. Hose, diatomite filter elements, fabric tanks, ion exchange resins, and similar water-absorbing components which could not be decontaminated satisfactorily were discarded in the AEC dump.

5. Results. Appendix D (Tables II through VII) gives summarized chemical and radiological results for all six runs. Figure 11 is a plot of dissolved solids and activity of water contaminated with cesium 137-barium 137 versus time during a typical cycle of the electrodialysis demineralizer (Cycle 4, Run 6).

Dosimetry data are shown in Appendix E (Tables VIII through XIII).

Appendix E, Table VIII, gives data on the use of the water monitoring method for determining radioactivity in water under field conditions.

Appendix E, Table IX, gives the dosimetry data obtained by exposing film badges and pocket dosimeters at strategic points in the Mobile Water Purification Unit during operations.

Appendix E, Table X, gives the dosimetry data obtained by exposing film badges and pocket dosimeters at strategic points in the Mobile Ion Exchange Unit during operations.

Appendix E, Table XI, gives the radiation data obtained at the cation exchange column of the Mobile Ion Exchange Unit during regeneration with sodium chloride following Run 4 with cesium 137-barium 137.

Appendix E, Table XII, gives the radiation data obtained by exposing film badges at various points of the electrodialysis unit during Run 6.

Appendix E, Table XIII, gives the dosimetry data for all personnel participating in or observing the test program.

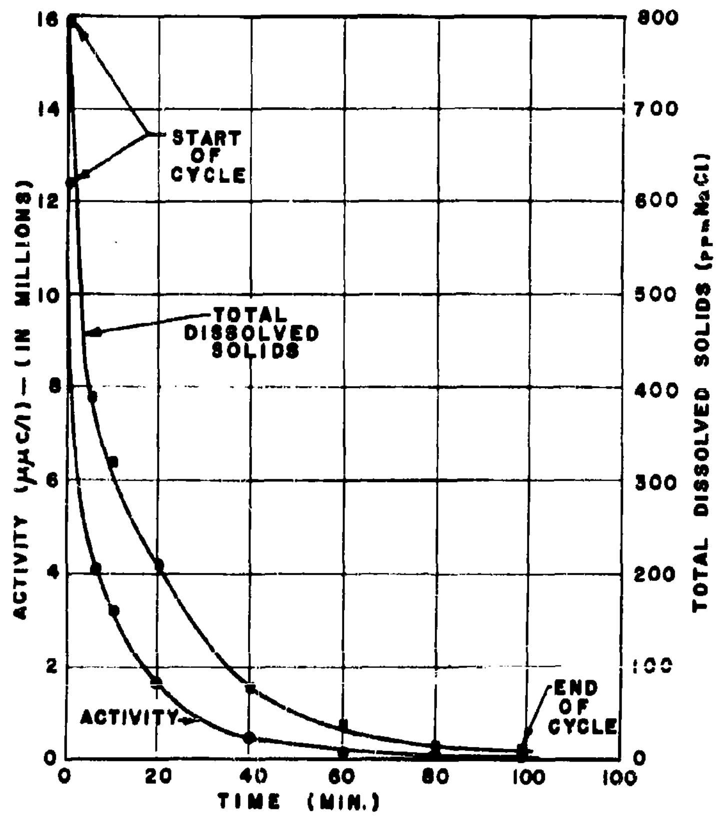

Fig. 11. Plot of total dissolved solids and activity of water contaminated with cesium 137-barium 137 versus time during a typical cycle of the electrodialysis demineralizer (Cycle 4, Run 6).

III. DISCUSSION

6. Discussion of Runs. The results of all six runs, summarized in Table I, are discussed below.

a. Run 1. Run 1 showed a 99.2-percent removal of pulverized bomb debris from water by the processes of coagulation and filtration. This effective removal was directly related to the fact that the bomb debris, although finely ground to an average particle size of 3 microns, was only 0.5-percent soluble in water in respect to its radioactive component. The Mobile Water Purification Unit, with its inherent coagulation and filtration equipment, is designed to remove turbidity from water and consequently was effective in removing the insoluble bomb debris. It is noted that the bomb debris consisted primarily of fission products entrapped in fused volcanic tuff. Since the tuff was principally silicious in nature, the low solubility was readily explainable. Other types of bomb debris might exhibit a higher solubility, with a resulting lower percentage removal from water by coagulation and filtration. A sand filter in conjunction with coagulation in the Erdlator accomplished essentially the same removal as the standard equipment.

b. Run 2. Run 2 was conducted in an effort to challenge the equipment with a more formidable material. Pulverized bomb debris was subjected to a 25-minute fusion with caustic soda in an attempt to obtain a material more soluble in water. However, when neutralized with hydrochloric acid and added to the feedwater, the fused debris dissolved only to the extent of 2.8 percent of the contained radioactivity. The coagulation and filtration, as expected, removed the insoluble matter, for a removal of 97.2 percent of the total activity. The effluent from the Mobile Water Purification Unit was pumped through the Mobile Ion Exchange Unit where the cation exchanger on the hydrogen cycle removed most of the remaining dissolved activity, for an overall removal of 99.9 percent.

c. Run 3. In Run 3, the equipment was challenged with perhaps the most dangerous radioactive contaminant available: soluble strontium 90-yttrium 90. The Mobile Water Purification Unit proved to be effective in removing the yttrium 90 daughter (96.7-percent removal). The unit was ineffective in removing the strontium 90 parent (13.3-percent removal). Since yttrium 90 soon breeds into the remaining strontium 90, little was accomplished. However, the cation exchanger on the hydrogen cycle removed most of the soluble material which passed the Mobile Water Purification Unit, for an overall activity removal greater than 99.9 percent. It is interesting to note that, although diatomite filtration was ineffective for the removal of the soluble activity, the sand filter was relatively effective. It is believed that this removal by the sand particles was due to surface adsorption resulting from unsatisfied electrical charges on the sand surface. Eventually, as these surface charges were satisfied, the sand filter would lose its effectiveness. At the conclusion of the run, the cation resin was regenerated with hydrochloric acid, but only 29 percent of the activity was removed.

Table I. Summary of Water Decontamination Studies

Run	Date (1959)	Contaminant	Process	Radioactivity (picocuries per liter) Influent	Radioactivity (picocuries per liter) Effluent	Percent Removal (cumulative)
1	14, 15 Oct	Bomb debris, 3 microns	Coagulation and filtration	667,000	5,400	99.2
2	20 Oct	Bomb debris, fused with NaOH	Coagulation and filtration	1,550,000	44,500	97.2
			Cation exchange (H)	44,500	7,100	99.5
3	23, 26 Oct	Strontium 90-yttrium 90	Coagulation and filtration			
			Strontium 90	1,010,000	876,000	13.3
			Yttrium 90	769,000	25,000	96.7
			Cation exchange (H)			
			Strontium 90	876,000	700 ($Sr^{90}+Y^{90}$)	>99.9
			Yttrium 90	25,000		
4	28, 29 Oct	Cesium 137-barium 137	Coagulation and filtration	12,700,000	12,400,000	2.4
			Cation exchange (H)	12,400,000	3,500	>99.9
5	31 Oct 2 Nov	Strontium 90-yttrium 90	Cation exchange (Na)			
			Strontium 90	1,107,000	50,000	95.5
			Yttrium 90	903,000	229,000	74.6
6	28 Oct-3 Nov	Cesium 137-barium 137	Electrodialysis	7,700,000	10,000	99.9

d. Run 4. In Run 4, another dangerous fission product contaminant was used: soluble cesium 137-barium 137. The Mobile Water Purification Unit removed only 2.4 percent of this material. The cation bed on the hydrogen cycle in the Mobile Ion Exchange Unit removed the great bulk remaining, however, for an overall removal of 99.9 percent. Regeneration with sodium chloride at the end of the run removed 77 percent of the activity held by the resin.

e. Run 5. Run 5 was conducted to demonstrate the effectiveness of a cation exchange resin on the sodium cycle for removing cesium 137-barium 137 from water. The contaminated water was fed directly to the cation exchanger without prior coagulation or filtration. The process proved to be inferior to cation exchange on the hydrogen cycle with pretreatment of the influent water. The strontium 90 removal was 95.5 percent, whereas the yttrium 90 removal was only 76.6 percent. The relatively low removal of yttrium 90 was probably due to the established tendency of yttrium 90 to hydrolyze at pH values over 4.5 and to form radiocolloids by attachment to particles of dust, silica, or the like, inevitably present even in clear water, and thus become unsusceptible to removal by ion exchange.

f. Run 6. Run 6 was conducted with the electrodialysis unit using water contaminated with cesium 137-barium 137. The unit was set to give high demineralization, with a reduction in output to 7 gph. The unit demineralized the water from 887 ppm tds to 1.5 ppm tds, with a 99.9-percent reduction in the cesium 137-barium 137 content.

All runs were conducted without excessive radiation exposure to operating personnel. The maximum exposure observed for the entire 6-week test period was 330 milliroentgen equivalent man (mrem) for the person involved in the grinding of the highly active bomb debris and in the diluting and aliquoting of the radioisotope concentrates used as soluble contaminants. This dosage is well below the 3,000 mrem permitted for any given 13-week period. The operator of the Mobile Ion Exchange Unit received an accumulated radiation dose of only 30 mrem over a period of 46 hours of operation.

Certain sections of the equipment in both the Mobile Water Purification Unit and Mobile Ion Exchange Unit became more radioactively "hot" than others, as shown by the film badges attached to key segments to measure the cumulative radiation for each test run. The highest radiation readings were obtained during Run 4 with cesium 137-barium 137 as the contaminant. During this run, 50 to 60 mrem dose was accumulated on the outside surface of the Erdlator opposite the slurry pool and on the outside surface of the bottom section of the sludge concentrator. Because there is continuous withdrawal of slurry to waste in the Erdlator operation, radiation levels in the

slurry pool area were found to reach a plateau and remain there until a change occurred in the concentration of radioactive materials in the input water. During Run 4, the maximum specific activity in the Mobile Water Purification Unit (8.3 mr/hr) occurred on the outside surface of the Erdlator. In the Mobile Ion Exchange Unit, the highest cumulative reading (1,800 mrem) was obtained on the outside surface of the cation exchange tank. A specific activity reading of 600 mr/hr was obtained at the same point. This reading decreased from 600 mr/hr to 5 mr/hr during regeneration.

The data obtained with the beta-gamma survey meter for monitoring contaminated water indicate that this method is satisfactory for use in the field. The method does not presume to be as accurate as the standard laboratory method of evaporating a known volume to dryness on a planchet and counting in a laboratory counter; however, the method has the advantage of being simply and quickly performed using a field instrument. Accuracy of this method is considered acceptable under field conditions. The latest Geiger-Müller survey instrument produced by the U. S. Army Signal Corps is the "Radiacmeter IM-141/PDR-27J." This instrument is a portable, watertight, battery-operated, partially-transistorized, radiation detector designed for field use.

Water-decontamination results must be evaluated in terms of existing drinking-water tolerances. It is important to know whether the raw water is below tolerance and suitable for drinking or whether the water is above tolerance and must be subjected to decontamination procedures. It is also important to know whether the treated water has, indeed, been made safe to drink after the selected decontamination procedure. The U. S. Army drinking-water tolerance (maximum permissible concentration (MPC)) is based on total activity, regardless of individual radioisotope or radioisotopes present, and applies to 1-year consumption under emergency conditions. Significant concentrations of radioactivity in water related to this study are as follows:

Item	Picocuries per Liter
OCDM Recommended Acceptable Tolerance for 30-day consumption.	30,000,000
U. S. Army Emergency Maximum Permissible Concentration for 1-year consumption.	300,000
Lifetime Maximum Permissible Concentration - National Bureau of Standards Handbook 69.	100
Range of contaminated feedwater used in these studies.	667,000 to 12,700,000
Range of final effluents obtained in these studies.	700 to 279,000

All runs in this study were made with feed water contaminated to levels well above the U. S. Army 1-year emergency drinking-water tolerance. The Mobile Water Purification Unit and the Mobile Ion Exchange Unit used either separately or in series, as required, were able to reduce the level of contamination to below emergency drinking-water tolerance.

IV. CONCLUSIONS

7. Conclusions. It is concluded that:

a. Standard field water purification equipment employing continuous coagulation and diatomite filtration is capable of removing over 99 percent of insoluble or suspended radioactive contaminants from water.

b. Standard water purification equipment employing continuous coagulation and diatomite filtration followed by a water demineralization process is capable of removing over 99 percent of the insoluble and soluble radioactive contaminants from water.

c. Diatomite filter membranes, ion exchange resins, permselective membranes, and equipment in contact with radioactive liquids and subject to corrosion contain some radioactivity after normal decontamination; and studies after extended periods of operation are necessary to develop better methods of decontamination or to determine field capabilities for operation, repair, and maintenance of this equipment.

APPENDICES

APPENDIX A

AUTHORITY

Item No. 2098
CETC Mtg #239

R & D SUB PROJECT CARD	TYPE OF REPORT: PROGRESS	REPORT CONTROL SYMBOL: CSCRD-1(R1)

1. SUBPROJECT TITLE: REMOVAL OF CBR CONTAMINANTS FROM WATER (U)	2. SECURITY OF PROJECT: U	3. PROJECT NO.: 8-75-00-000
	4. INDEX NUMBER: 8-75-07-460	5. REPORT DATE: 31 Dec 59
6. BASIC FIELD OR SUBJECT: Water Supply and Sanitation	7. SUB FIELD OR SUBJECT SUB GROUP: Water Development, Techniques & Distribution	7A. TECH. OBJ.: SO-9
8. COGNIZANT AGENCY: C of E	12. CONTRACTOR AND/OR LABORATORY: Engr Res & Dev Lab	CONTRACT/W. O. NO.:
9. DIRECTING AGENCY: Res & Dev Div, OCE		
10. REQUESTING AGENCY: OCE		
11. PARTICIPATION AND/OR COORDINATION: Chem Corps (P)-(Facilities) (Technical Personnel) (Equipment) (Project No. 4-75-05-001)	13. RELATED PROJECTS:	17. EST. COMPLETION DATES: RES. Cont; DEV.; TEST; OP. EVAL.
	14. DATE APPROVED: 5 Dec 52, by GSUSA	
	15. PRIORITY: 1-B; 16. MAJOR CATEGORY: 5600	
19. REPLACED PROJECT CARD AND PROJECT STATUS: Supersedes project card dated 31 Dec 58.		

18. FY.	FISCAL ESTIMATES
60	38M
61	35M
P/A	40M

20. REQUIREMENT AND/OR JUSTIFICATION

There is a requirement for determination of the effectiveness of Army field water purification equipment and processes now standard and under development for removing chemical, biological, and radioactive agents from water to be used for drinking and other purpose. This requirement has been established by the threat of new and more efficient agents and weapons of war.

21. BRIEF OF PROJECT AND OBJECTIVE

a. Brief:
  (1) Objective:
    (a) Determination of the capabilities and limitations of Army field water supply equipment and water treatment processes now standard or under development with respect to purifying water containing chemical, biological, and radioactive contaminants, as determined by the Chemical Corps and other agencies.
    (b) Establishment, where necessary, of new water treatment techniques, on the basis of coordi[illegible] information from Chemical Corps, for the removal of these contaminants from water.

22. OASD (R & D)	SN.	CN.	C.	X.	I.	C.

DD FORM 1 APR 55 613 — REPLACES DD FORM 613, 1 JAN 52. PAGE 1 OF 4 PAGES

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SUB
R&D/PROJECT CARD
CONTINUATION SHEET

2098/239

1. SUBPROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NO.
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	4. INDEX NUMBER 8-75-07-460	5. REPORT DATE 31 Dec 59

Block 21a Continued

(2) Military Characteristics:
There are no military characteristics applicable to this project. Should design changes in equipment be required, the work will be accomplished under this project.

b. Approach:

(1) The studies and tests to be conducted under this project with respect to radioactive contaminants will be accomplished under arrangements already existing between the Corps of Engineers, the Chemical Corps, and the Atomic Energy Commission in connection with superseded project 8-75-05-008. Activities in this field will be conducted by the Corps of Engineers detachment at ORNL, Oak Ridge, Tennessee. All contaminants will be procured from ORNL, and technical assistance of ORNL specialists will be obtained when necessary.

(2) This project will be conducted on full size field serviceable equipment. The ORNL representative equipment and processes will be evaluated using both mixed fission products and potential RW contaminants. To reduce the possibility of errors and to demonstrate associated problems, dosages of contaminants used will be the largest dosages expected under combat conditions. Should the data show that these dosages cannot be effectively handled, then the limit of effectiveness of equipment or processes will be established. The same general concept will apply to the studies of chemical and biological agents. In the case of biological agents, the potential hazard involved dictates that simulated agents (non-pathogenic organisms) be used in many tests.

(3) All studies and tests to be conducted using biological and chemical contaminants will be carefully coordinated and accomplished with the participation of the Chemical Corps. All contaminants will be furnished by the Chemical Corps, together with special personnel required to safely handle the contaminants and to conduct special analyses. All equipment to be tested will be furnished by the Corps of Engineers. Tests will be conducted at Chemical Corps installations such as Fort Detrick, Frederick, Md.; Chemical Corps Medical Laboratories, Army Chemical Center, Md.; and such other installations as may be designated, and at the Engineer Research and Development Laboratories, as dictated by the requirements of the individual test.

(4) Where chemical, biological, and radiological agents are being studied, all necessary safety precautions will be used.

(5) Report will be submitted covering each major grouping of contaminants used. A final project report will be submitted which will emphasize the field application of the information resulting from this project.

R&D/SUB PROJECT CARD
CONTINUATION SHEET

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BLOCK 21b Continued

While tests on the several contaminants may be carried out simultaneously, the general order of work will be to consider radioactive, chemical, and biological agents in turn.

c. Subtasks:
Techniques for handling chemical and biological contaminants and the disposal of wastes must be developed. These problems are not considered insurmountable and will be resolved by qualified personnel of the Chemical Corps.

d. Other Information:

(1) Scientific Research:
None.

(2) References:
Requirement for equipment and methods for decontaminating water is contained in the Army Equipment Development Guide, Paragraph 217.

(3) Discussion:

(a) The potential problems associated with chemical, biological, and radioactive contaminants with respect to field water supplies have greatly increased in recent years by marked advances in the development of contaminants and weapons. Corps of Engineers Project 8-75-05-008 provided for a basic study and evaluation of the problems of removing AW and RW contaminants from water. Significant data have been developed under 8-75-05-008. These data have shown that standard field water purification equipment with the use of additional supplies in the coagulation phases of the water purification process is effective in meeting minimum standards established for radioactive contamination tolerances in drinking water. Procedures with respect thereto are being prepared at this time. This project is intended to supersede Project 8-75-05-800 but will not duplicate work already done under the former project. It is expected that the project will result not only in establishing the capabilities and limitations of equipment and methods but will provide data to guide personnel training procedures. It is to be noted that the military importance of many potentially excellent contaminants is reduced by the inability of the user to protect friendly forces. It is possible, therefore, that the work under this project through development of protective measures with respect to water, may bring into sharp focus the offensive capabilities of agents which today are not suitable for combat use.

(b) Agencies interested in this project, in addition to the Corps of Engineers, with which liaison will be maintained and which will be

SUB
R&D PROJECT CARD
CONTINUATION SHEET

2098/239

1. SUBPROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NO.
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Block 21d Continued

furnished copies of the reports on the project are the Department of the Navy, Department of the Air Force, Chemical Corps, Army Medical Service, CONARC.

APPENDIX B

ANALYSES AND OPERATING DATA

CHEMICAL ANALYSIS J-11 WELL WATER

Exhibit 1

Item	Average Value During Test Period
pH	7.7
Color (units)	12
Turbidity (units)	5
Total alkalinity (ppm $CaCO_3$)	85
Total hardness (ppm $CaCO_3$)	252
Magnesium (ppm $CaCO_3$)	48
Calcium (ppm $CaCO_3$)	204
Sodium (ppm Na)	212
Sulfate (ppm SO_4)	576
Silica (ppm SiO_2)	59
Chloride (ppm Cl)	18
Iron (ppm Fe)	1.1

RADIOCHEMICAL ANALYSIS BOMB DEBRIS USED AS WATER CONTAMINANT[a] (Normalized to 23 October 1959)

Exhibit 2

Radioactive Substance	Specific Activity (picocuries[b] per gram of debris)
Strontium 89	10,000
Strontium 90	55,000
Yttrium 90	55,000
Trivalent rare earths	10,200,000
Ruthenium 106-Rhodium 106	470,000
Cesium 137 + Cesium 134	50,000
Zirconium 95-Niobium 95	5,100,000
Unidentified (by difference)	3,100,000
Total beta emitters	19,040,000

(a) Data furnished by Reynolds Electrical and Engineering Co., Inc.

(b) Picocurie is equal to 10^{-12} curie.

Exhibit 3 OPERATING DATA FOR A TYPICAL RUN MOBILE ION EXCHANGE UNIT

Total operating time for cation exchanger	14.7 hr
Total operating time for anion exchanger	11.5 hr
Capacity of cation exchange resin	32 Kgr $CaCO_3$/cu ft
Capacity of anion exchange resin	31.5 Kgr $CaCO_3$/cu ft
Volume of water from which cations were removed by cation exchanger	22,000 gal.
Volume of water from which anions were removed by anion exchanger	17,250 gal.
Volume of demineralized water used for regeneration	2,000 gal.
Total dissolved solids content of demineralized water (as $CaCO_3$)	1 gr/gal.

APPENDIX C

DECONTAMINATION PROCEDURES

RUN 1 — Exhibit 1

DECONTAMINATION OF WELL WATER CONTAMINATED WITH AGED BOMB DEBRIS BY THE MOBILE WATER PURIFICATION UNIT AND BY COAGULATION AND SAND FILTRATION

DATE: 14 October and 15 October 1959

OBJECTIVE: To evaluate the Mobile Water Purification Unit for the removal from well water of radioactivity due to finely ground aged bomb debris (simulating heavy fallout) and to compare the effectiveness of the diatomite filter of the unit with a rapid sand filter for this removal.

PROCEDURE:

1. Prepare contaminated feed water for each part of run as follows:

   a. Add to each of three 3,000-gal. tanks of J-11 well water 1 lb 12 oz ground bomb debris (3-micron average particle size).

   b. Mix thoroughly with wooden paddle.

   c. Start recirculating pump and maintain continuous agitation of feed water.

   d. Repeat mixing with wooden paddle at 15-min intervals during run.

2. Operate Mobile Water Purification Unit as follows:

   a. Run at 30-gpm rate.

   b. Operate Erdlator agitator at 124 rpm.

   c. Add following chemical dose:

      $FeCl_3$ - 50 ppm
      Limestone - 100 ppm
      $Ca(OCl)_2$ - 2 ppm

d. Operate filter with 1 lb diatomite precoat and 20 ppm body feed.

3. Bypass part of coagulated water through sand filter at rate of 3 gpm/ft^2.

4. Sample contaminated feed water, coagulated water, diatomite-filter effluent, and sand-filter effluent at hourly intervals for analysis.

RUN 2 Exhibit 2

DECONTAMINATION OF WELL WATER CONTAMINATED WITH AGED BOMB DEBRIS FUSED WITH SODIUM HYDROXIDE BY THE MOBILE WATER PURIFICATION UNIT AND THE MOBILE ION EXCHANGE UNIT IN SERIES

DATE: 20 October 1959

OBJECTIVE: To evaluate the effectiveness of the Mobile Water Purification Unit and the Mobile Ion Exchange Unit, operated in series, for the removal of radioactivity from well water contaminated by soluble and insoluble activity from aged bomb debris previously fused with sodium hydroxide.

PROCEDURE: 1. Prepare contaminated feed water as follows:

a. Fuse 1 lb ground bomb debris (10-micron average particle size) with 5 lb sodium hydroxide in insulated iron pot over butane burner.

b. Heat 35 min (10 min to melting of sodium hydroxide and 25 min controlled boiling of mixture).

c. Pour fusion mixture while hot into a 60-gal. steel drum.

d. Repeat steps a through c until 12 lb of debris are fused, adding each fusion to the steel drum.

e. Add 3 gal. of water to fusion mixture.

f. Carefully neutralize with 21 gal. hydrochloric acid (31 percent) added in 1- to 3-gal. portions, stirring frequently to break up chunks of solidified fusion mixture.

g. Dilute to 40 gal. with water.

h. Distribute mixture equally into four carboys.

i. Add contents of one carboy to each of four 3,000-gal. tanks of J-11 well water.

j. Mix thoroughly with wooden paddle.

k. Start recirculating pump and maintain continuous agitation of feed water.

1. Repeat mixing with wooden paddle at 15-min intervals during run.

2. Operate Mobile Water Purification Unit as follows:

   a. Run at 30-gpm rate.

   b. Operate Erdlator agitator at 124 rpm.

   c. Add following chemical dose:

      $FeCl_3$ - 25 ppm
      Limestone - 80 ppm
      $Ca(OCl)_2$ - 3 ppm

   d. Operate filter with 1 lb diatomite precoat and 20 ppm body feed.

3. Pass filtered water from Mobile Water Purification Unit to 3,000 gal. tank.

4. Withdraw filtered water as feed to Mobile Ion Exchange Unit* operated at 25 gpm.

5. Sample contaminated feed water, coagulated water, diatomite-filter effluent, cation, anion, and mixed-bed column effluents at hourly intervals for analysis.

* Cation resin - IR-120 (H)
Anion resin - IR-45 (OH)
Mixed-bed resins - Permutit Q (H)
Permutit S2 (OH)

RUN 3 Exhibit 3

DECONTAMINATION OF WELL WATER CONTAMINATED WITH STRONTIUM 90-YTTRIUM 90 BY THE MOBILE WATER PURIFICATION UNIT AND THE MOBILE ION EXCHANGE UNIT IN SERIES AND BY COAGULATION AND SAND FILTRATION

DATE: 23 and 26 October 1959

OBJECTIVE: To evaluate the effectiveness of the Mobile Water Purification Unit and the Mobile Ion Exchange Unit, operated in series, for removing Sr^{90}-Y^{90} radioactivity from well water and to evaluate the process of coagulation and sand filtration for the removal of the same activity.

PROCEDURE:

1. Prepare contaminated feed water for each part of run as follows:

   a. Add to each 3,000-gal. tank of J-11 well water a quantity of contaminant calculated to contain 11 millicuries of Sr^{90}-Y^{90} activity, prepared by diluting and aliquoting the concentrate obtained from the Oak Ridge National Laboratories.

   b. Mix thoroughly with wooden paddle.

   c. Start recirculating pump and maintain continuous agitation of feed water.

   d. Repeat mixing with wooden paddle at 15-min intervals during run.

2. Operate Mobile Water Purification Unit as follows:

   a. Run at 28-gpm rate.

   b. Operate Erdlator agitator at 124 rpm.

   c. Add following chemical dose:

      $FeCl_3$ - 42 ppm
      Limestone - 146 ppm
      $Ca(OCl)_2$ - 4 ppm

   d. Operate filter with 1 lb diatomite precoat and 20 ppm body feed.

3. Bypass part of coagulated water through sand filter at 3-gpm/ft^2 rate.

4. Pass balance of coagulated water through diatomite filter of Unit to a 3,000-gal. tank.

5. Withdraw diatomite filtered water as feed to Mobile Ion Exchange Unit* operated at 25 gpm.

6. Sample contaminated feed water, coagulated water, diatomite-filter and sand-filter effluents, cation, anion, and mixed-bed column effluents at hourly intervals for analysis.

* Resins in unit same as in Run 2.

RUN 4 Exhibit 4

DECONTAMINATION OF WELL WATER CONTAMINATED WITH CESIUM 137-BARIUM 137 BY THE MOBILE WATER PURIFICATION UNIT AND THE MOBILE ION EXCHANGE UNIT IN SERIES AND BY COAGULATION AND SAND FILTRATION

DATE: 28 October and 29 October 1959

OBJECTIVE: To evaluate the effectiveness of the Mobile Water Purification Unit and the Mobile Ion Exchange Unit, operated in series, for removing Cs^{137}-Ba^{137} radioactivity from well water and to evaluate the process of coagulation and sand filtration for removal of the same activity.

PROCEDURE:

1. Prepare contaminated feed water for each part of the run as follows:

   a. Add to each of three 3,000-gal. tanks of J-11 well water a quantity of contaminant calculated to contain 120 millicuries of Cs^{137}-Ba^{137} activity, prepared by diluting and aliquoting the concentrate obtained from the Oak Ridge National Laboratories.

   b. Mix thoroughly with wooden paddle.

   c. Start recirculating pump and maintain continuous agitation of feed water.

   d. Repeat mixing with wooden paddle at 15-min intervals during run.

2. Operate Mobile Water Purification Unit as follows:

   a. Run at 28-gpm rate.

   b. Operate Erdlator agitator at 124 rpm.

   c. Add following chemical dose:

      $FeCl_3$ - 42 ppm
      Limestone - 146 ppm
      $Ca(OCl)_2$ - 4 ppm

   d. Operate filter with 1 lb diatomite precoat and 17 ppm body feed.

3. Bypass part of coagulated water through sand filter at 3-gpm/ft^2 rate.

4. Pass balance of coagulated water through diatomite filter of Mobile Water Purification Unit to a 3,000-gal. tank.

5. Withdraw diatomite filtered water as feed to Mobile Ion Exchange Unit* operated at 25-gpm rate.

6. Sample contaminated feed water, coagulated water, diatomite-filter effluent, sand-filter effluent, cation, anion, and mixed-bed column effluents at hourly intervals for analysis.

* Resins in unit same as in Run 2.

RUN 5 Exhibit 5

DECONTAMINATION OF WELL WATER CONTAMINATED WITH STRONTIUM 90-YTTRIUM 90 BY THE MOBILE ION EXCHANGE UNIT USING CATION EXCHANGE RESIN ON THE SODIUM CYCLE

DATE: 31 October and 2 November 1959

OBJECTIVE: To evaluate the effectiveness of a cation exchange resin on the sodium cycle for the removal of Sr^{90}-Y^{90} activity from well water.

PROCEDURE:

1. Prepare contaminated feed water as in Run 3.

2. Pump contaminated water through the Mobile Ion Exchange Unit cation column only, with resin (IR-120) on the sodium cycle.

3. Operate Unit at 25-gpm rate.

4. Sample contaminated feed water and cation exchange column effluent at hourly intervals for analysis.

Exhibit 6 RUN 6

DECONTAMINATION OF WELL WATER CONTAMINATED WITH CESIUM 137-BARIUM 137 BY THE AQUAMITE-30B ELECTRODIALYSIS DEMINERALIZATION UNIT

DATE: 28 October through 3 November 1959

OBJECTIVE: To evaluate the Aquamite-30B Electrodialysis Demineralization Unit for the removal of radioactivity from well water contaminated with Cs^{137}-Ba^{137} activity.

PROCEDURE:

1. Prepare contaminated feed water* as in Run 4.
2. Pump contaminated water to Unit at 35-gph feed rate with desired conductivity setting.
3. Sample contaminated feed water, electrode stream, brine stream, and product water for analysis during each cycle.

---

* Analysis of Feed Water: (ppm units)

Ca, 84.0; Mg, 10.2; Fe, 0.8; Na, 168; Cl, 18.5; SO_4, 522; SiO_2, 64; HCO_3, 53.8;
Total dissolved solids (TDS), 887; pH, 7.8.

APPENDIX D

DECONTAMINATION RESULTS

Table II. Run 1 - Decontamination of Well Water Contaminated with Aged Bomb Debris by the Mobile Water Purification Unit and by Coagulation and Filtration

	CONTAMINATED WATER								COAGULATED WATER			DIATOMITE FILTER EFFLUENT					SAND FILTER EFFLUENT			SLUDGE
SAMPLE TIME	TEMPERATURE (°F)	pH	ALKALINITY (ppm $CaCO_3$)	HARDNESS (ppm $CaCO_3$)	TURBIDITY (UNITS)	COLOR (UNITS)	RADIOACTIVITY (10^3 pc/l) UNFILTERED	RADIOACTIVITY (10^3 pc/l) FILTERED*	TURBIDITY (UNITS)	RADIOACTIVITY (10^3 pc/l) UNFILTERED	RADIOACTIVITY (10^3 pc/l) FILTERED*	pH	ALKALINITY (ppm $CaCO_3$)	TURBIDITY (UNITS)	RADIOACTIVITY (10^3 pc/l) UNFILTERED	RADIOACTIVITY (10^3 pc/l) FILTERED*	TURBIDITY (UNITS)	RADIOACTIVITY (10^3 pc/l) UNFILTERED	RADIOACTIVITY (10^3 pc/l) FILTERED*	RADIOACTIVITY (10^3 pc/l)
PART A 14 OCT 1959																				
0900		7.7	80	236	6.6	>100	510	9.53	2.4	71.1	47.4	6.1	68	0.2	0	0	<0.1	7.1	7.1	
1000		7.7					725	0	1.4	47.4	0	6.5	62	<0.1	4.7	0	<0.1	2.4	2.4	
1100	65						521	0	1.0	83.6	7.1	6.3	40	<0.1	2.4	0	<0.1	2.4	4.7	
1200		7.6					430	4.7	2.1	118.0		6.4	53	<0.1	2.4		<0.1	2.4		
1300	76	7.7	88	236	4.9	>100	320		4.8	413.8		6.4	56	1.0	11.8		<0.1	4.7		
PART B 15 OCT 1959																				
0900	68	7.6	88	232	5.6	>100	1090	0	2.6	71.1	0	6.6	70	<0.1	4.7	2.4	<0.1	2.4	0	
1000		7.7					664	4.7	9.6	450.0	2.4	6.2	5.8	9	21.3	0	<0.1	0	0	
1100	71	7.7					427		4.8	261.0		6.8	74	<0.1	0		<0.1	0.5		
1200		7.7					735		1.6	83.8		6.8	76	<0.1	4.7		<0.1	5.9		
1300	72	7.7	88	252	4.4	>100	972		8	23.7		6.7	69	<0.1	3.6		18			60,400
1400		7.8					924		5	23.7		6.8	[illegible]0	<0.1	3.6		<0.1	10.7		57,200
AVERAGE	70	7.7	86	234	5.4	>100	667	32	2.0	150.0	11.4	6.5	68	1.9	5.4	0.5	1.0	3.9	2.6	58,800
SOLUBLE ACTIVITY (%)							0.5			7.6					9.3			66.7		

* THRU MEMBRANE FILTER

RADIOACTIVITY REMOVAL	
PROCESS	REMOVAL (%)
COAGULATION	77.3
COAGULATION & DIATOMITE FILTRATION	99.2
COAGULATION & SAND FILTRATION	99.4

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Table III. Run 2 - Decontamination of Well Water Contaminated with Aged Bomb Debris Fused with Sodium Hydroxide by the Mobile Water Purification Unit and the Mobile Ion Exchange Unit in Series

	Contaminated Water								Coagulated Water			Diatomite Filter Effluent						Cation Column Effluent		Anion Column Effluent			Mixed Bed Effluent								Sludge
Sample Time	Temperature (°F)	pH	Alkalinity (ppm CaCO3)	Hardness (ppm CaCO3)	Turbidity (units)	Color (units)	Radioactivity (10^3 μμc/l) Unfiltered	Radioactivity (10^3 μμc/l) Filtered*	Turbidity (units)	Radioactivity (10^3 μμc/l) Unfiltered	Radioactivity (10^3 μμc/l) Filtered*	pH	Alkalinity (ppm CaCO3)	Turbidity (units)	Color (units)	Radioactivity (10^3 μμc/l) Unfiltered	Radioactivity (10^3 μμc/l) Filtered*	pH	Radioactivity (10^3 μμc/l)	pH	Alkalinity (ppm CaCO3)	Radioactivity (10^3 μμc/l)	pH	Alkalinity (ppm CaCO3)	Hardness (ppm CaCO3)	Turbidity (units)	Color (units)	Chloride (ppm Cl)	Sulfate (ppm SO4)	Radioactivity (10^3 μμc/l)	Radioactivity (10^3 μμc/l)
29 October 1959																															
1040	62	7.3	86	246	96	>100	1,600	35.6	131	893	37.6	6.7	72	33		85.5	35.6														
1100		7.3					1,490	38.6	16	190	25.7	6.0	66	8		59.3	25.7														
1200	62	7.3					1,920	47.5	12	237	23.7		69	<0.1		36.6	23.7	1.6	4.7	7.3	4.3	0	5.8	0		<0.1				0	55,000
1300	62	7.3					1,600	36.5	10	110	23.7	6.9	64	<0.1		23.7	23.7	1.7	9.3	3.9	3.6	0	4.6	2	0	<0.1	0	0	0	2.4	
1400	62	7.3		248	98	>100	1,630	35.6	32	356	23.7	6.9	64	<0.1		47.4	38.6	1.7	7.6	3.5	2.8	0	4.2	0	0	<0.1				0	
1500		7.1					1,500	47.4	86	332	23.7	6.8	64	<0.1		35.6	28.7											1.5	0		31,300
1600	80	7.4					1,560	47.4	10	142	35.6	6.8	68	<0.1	0	35.6	33.6														
1640		7.6					1,560	39.2	1	107	23.7	6.9	32	<0.1	0	35.6	23.7														
Average	66	7.4	86	246	97	>100	1,550	41.1	36	410	28.2	6.8	65		0	44.5	28.6	1.7	7.1	6.2	3.6	0	4.6	1	0	<0.1		0.8	0	0.8	32,200
Solubility (%)							2.6			6.5						63.6															

* Type HA Millipore filter

Radioactivity Removal	
Process	Removal (%)
Coagulation.	73.5
Coagulation & diatomite filtration.	97.2
Coagulation, diatomite filtration & cation exchange.	99.6
Coagulation, filtration, cation exchange, anion exchange & mixed bed ion exchange.	>99.9

Table IV. Run 3 - Decontamination of Well Water Contaminated with Strontium 90-Yttrium 90 by the Mobile Water Purification Unit and the Mobile Ion Exchange Unit in Series and by Coagulation and Sand Filtration

Time	Contaminated Water: Temp (°F)	pH	Alkalinity (ppm CaCO3)	Hardness (ppm CaCO3)	Turbidity (units)	Color (units)	Radioactivity Unfiltered (10^4 μμc/l)	Radioactivity Filtered* (10^4 μμc/l)	Coagulated Water: Turbidity (units)	Radioactivity Unfiltered (10^4 μμc/l)	Radioactivity Filtered* (10^4 μμc/l)	Diatomite Filter Effluent: pH	Alkalinity (ppm CaCO3)	Turbidity (units)	Radioactivity Unfiltered (10^4 μμc/l)	Radioactivity Filtered* (10^4 μμc/l)	Sand Filter Effluent: Turbidity (units)	Radioactivity Unfiltered (10^4 μμc/l)	Radioactivity Filtered* (10^4 μμc/l)	Cation Column Effluent: pH	Radioactivity (10^4 μμc/l)	Anion Column Effluent: pH	Alkalinity (ppm CaCO3)	Radioactivity (10^4 μμc/l)	Mixed Bed Effluent: pH	Alkalinity (ppm CaCO3)	Hardness (ppm CaCO3)	Turbidity (units)	Color (units)	Chloride (ppm Cl)	Silica (ppm SiO2)	Radioactivity (10^4 μμc/l)	Sludge: Radioactivity (10^4 μμc/l)
Part A [illegible]																																	
10:00		7.8	88	240	7	40	1,740	1,040	3	676	595	7.8	88	<0.1	635	566	<0.1																
[illegible]	73	7.9					1,775	962	1.5	1,018	912	7.6	84	84	843	751	<0.1	776	966														
[illegible]	72	7.8					1,510	1,000	20	1,030	993	7.6	88	<0.1	835	942	<0.1	769	785														
[illegible]		7.8					1,930	855	2.4	901	889	7.1	86	<0.1	866	919	<0.1	820	783	1.9	5	6.0	32	11	3.9		0	<0.1		1.3	0	5	
[illegible]		7.9	88	240	5	25	2,510	1,130	1	1,018	936	7.2	92	<0.1	924	820	<0.1	870	866	2.0	3	6.1	24	7	4.0	0		<0.1		1.0	0	0	
[illegible]	72	7.9					1,544	1,070	5	1,070	947	7.1	88	<0.1	866	914	<0.1	901	947	1.9		6.0	24	11	4.4	0		<0.1	0	1.5	0	2	32,640
4:00																				1.8	0	5.7	24	0	5.7	0	0	<0.1	0	4.5	0	0	
Average	7	7.8	58	250	5	32	1,750	1,020	7	910	878	7.1	87	8.1	832	860	<0.1	832	860	1.9	5	6.0	26	7	4.0	0	0	<0.1	0	2.1	0	2	32,600
Soluble Activity (%)							58			91					97			100															

Time	Contaminated Water: Temp (°F)	pH	Alkalinity (ppm CaCO3)	Hardness (ppm CaCO3)	Turbidity (units)	Color (units)	Radioactivity Unfiltered: 90 [illegible]	Unfiltered: [illegible]	Filtered*: 90 [illegible]	Filtered*: [illegible]	Coagulated Water: Turbidity (units)	Unfiltered: 90 [illegible]	Unfiltered: [illegible]	Filtered*: 90 [illegible]	Filtered*: [illegible]	Diatomite Filter Effluent: pH	Alkalinity	Turbidity	Unfiltered: 90 [illegible]	Unfiltered: [illegible]	Filtered*: 90 [illegible]	Filtered*: [illegible]	Sand Filter Effluent: Turbidity	Unfiltered: 90 [illegible]	Unfiltered: [illegible]	Filtered*: 90 [illegible]	Filtered*: [illegible]	Cation Column Effluent: pH	Radioactivity	Anion Column Effluent: pH	Alkalinity	Radioactivity	Mixed Bed Effluent: pH	Alkalinity	Hardness	Turbidity	Color	Chloride	Silica	Radioactivity
Part B [illegible]																																								
[illegible]		7.9	48	244	22	33	2,990	451	1,279	85	20	1,200	142	821	12	7.6	160	<0.1	993	46	959	96	5	776	23	832	35													
[illegible]	63	7.9					1,380	4.6	1,510	130	1.9	1,110	196	776	12	7.1	88	<0.1	982	21			<0.1	735	1.7	739	5													
[illegible]	65	7.9					1,610	358	1,960	162	1.9	1,280	196	901	12	7.1	92	<0.1	901	35	974	35	<0.1	716	116	1,002	2													
[illegible]		[illegible]					1,698	366	995	92	7	1,040	39	820	2	7.2	92	<0.1	875	5	757	7	<0.1	843	5	866	9	2.0	2	5.6	20	0	3.5	3	0	<0.1		20	0	0
[illegible]	69	7.9	46	260	5	7	1,660	381	1,310	196	8.1	866	9	762	9	7.2	92	<0.1	820	5	705	5	<0.1	620	5	951	7	1.9	0	5.8	22	0	3.6	0	0	<0.1		18	0	0
[illegible]		8.0					1,690	466	1,190	166	7	1,230	30	832	12	7.3	100	<0.1	832	2	901	0	<0.1	853	9	930		1.9	2	5.8	22	0	3.7	0	0	<0.1	2	21	0	0
[illegible]																												2.0	0	5.3	22	0	4.0	0	0	<0.1	0	16	0	0
4:00																												1.9	0	5.2	16	0	4.3	0	0	<0.1	0	11	0	0
[illegible]																												1.9	0	5.8	16	9	4.5	4	2	<0.1	0	11	0	7
Average	60	7.9	46	252	16	21	1,780	446	1,216	130	12	1,101	90	818	10	7.2	96	<0.1	901	13	857	13	0.9	784	28	854	12	1.9	0.7	5.5	20	1.5	3.9	0.3	0	<0.1	0	16	0	1.2
Sr^{90} Activity							1,060		982			920		735					876		820			132		651														
Y^{90} Activity							765		208			175		19					25		37			54		23														
Soluble Activity (%)							60					76							53					150																

* Thru membrane filter

** 176 mg/cm²

Y^{90} activity = average "[illegible]" activity × 1.92

Sr^{90} activity = average "[illegible]" activity minus Y^{90} activity.

Part A Strontium 90-Yttrium 90 Removal: Process	Removal (%)
Coagulation	45.3
Coagulation & diatomite filtration	52.3
Coagulation & sand filtration	52.5
Coagulation, diatomite filtration & cation exchange	99.7
Coagulation, diatomite filtration, cation exchange, anion exchange & mixed bed ion exchange	99.9

Part B Strontium 90-Yttrium 90 Removal: Process	Removal (%)	
Coagulation	Sr^{90} - 8.1	Y^{90} - 77.5
Coagulation & diatomite filtration	Sr^{90} - 13.3	Y^{90} - 96.7
Coagulation & sand filtration	Sr^{90} - 27.5	Y^{90} - 93.0
Coagulation, diatomite filtration & cation exchange	$Sr^{90}+Y^{90}$ > 99.9	
Coagulation, diatomite filtration, cation exchange, anion exchange & mixed bed ion exchange	$Sr^{90}+Y^{90}$ > 99.9	

Table V. Run 4 - Decontamination of Well Water Contaminated with Cesium 137-Barium 137 by the Mobile Water Purification Unit and the Mobile Ion Exchange Unit in Series and by Coagulation and Sand Filtration

Sample Time	Contaminated Water: Temperature (°F)	pH	Alkalinity (ppm $CaCO_3$)	Hardness (ppm $CaCO_3$)	Turbidity (units)	Color (units)	Conductivity (10^2 μmho) Unfiltered	Filtered*	Coagulated Water: Turbidity (units)	Conductivity (10^2 μmho) Unfiltered	Filtered*
PART 2, 22 OCTOBER 1959											
0800	65	7.4	84	232	40	>100	11,400	10,200	15	12,600	12,000
0900		7.3					11,700	11,000	13	11,900	11,000
1000	60	7.6					12,100	12,000	7	12,300	11,800
1100	67	7.7					12,300		7	11,900	
1200		7.7	88	216	1.6	45	13,000		9	13,100	
1300											
1345											
PART 3, 23 OCT											
0800	57	7.0	76	232	1.6	35	13,300		13	13,600	
0900		7.7					13,300		6	13,700	
1000	63	7.3					12,700		10	13,300	
1100	63	7.9					13,500		9	12,600	
1200		7.9	76	232	13	25	13,300		11	13,700	
1245		7.9					13,300		10	13,200	
1300											
1345											
AVERAGE VALUE	64	7.7	81	233	24	>51	12,700	11,300	11	12,800	11,600

Sample Time	Diatomite Filter Effluent: pH	Alkalinity (ppm $CaCO_3$)	Turbidity (units)	Conductivity (10^2 μmho) Unfiltered	Filtered*	Sand Filter Effluent: Turbidity (units)	Conductivity (10^2 μmho) Unfiltered	Filtered*
PART 2, 22 OCTOBER 1959								
0800	6.8	100	<0.1	12,300	12,300	<0.1	83	98
0900	6.7	72	<0.1	12,100	11,600	<0.1	71	110
1000	7.2	92	<0.1	10,100	10,900	<0.1	95	107
1100	7.0	84	4.8	11,700		<0.1	93	
1200	7.0	92	<0.1	12,300		<0.1	91	
1300								
1345								
PART 3, 23 OCT								
0800	7.0	84	<0.1	13,000		<0.1	319	
0900	7.1	84	<0.1	13,700		<0.1	474	
1000	7.2	88	<0.1	12,300		<0.1	450	
1100	7.2	94	<0.1	11,700		<0.1	500	
1200	7.2	94	<0.1	12,500		<0.1	319	
1245	7.3	94	<0.1	12,000		<0.1	379	
1300								
1345								
AVERAGE VALUE	7.1	90	<0.5	12,400	11,600	<0.1	250	

Sample Time	Cation Column Effluent: pH	Conductivity (10^2 μmho)	Anion Column Effluent: pH	Alkalinity (ppm $CaCO_3$)	Conductivity (10^2 μmho)	Mixed Bed Effluent: pH	Alkalinity (ppm $CaCO_3$)	Hardness (ppm $CaCO_3$)	Turbidity (units)	Color (units)	Chloride (ppm Cl)	Sulfate (ppm SO_4)	Radioactivity (10^3 μc/l)
PART 2, 22 OCTOBER 1959													
0800													
0900													
1000	2.6	0	5.8	8	9	4.8	8	8	<0.1	0	8	8	8
1100	1.9	2	5.3	12	5	4.4	8	8	<0.1	0	1	8	8
1200	1.8	8	5.6	12	8	4.9	8	8	<0.1	0	1	8	8
1300	2.1	7	5.7	10	5	4.6	8	8	<0.1	0	1	8	8
1345	2.2	7	5.3	12	8	4.5	1	1	<0.1	0	1	8	8
PART 3, 23 OCT													
0800													
0900													
1000	2.1	2	5.6	10	5	4.4	8	1	<0.1	8	1	8	8
1100	2.1		6.1	8		4.3	8	8	<0.1	8	1	8	
1200	2.1		5.6	6		4.3	8		<0.1	8	1	8	
1245		12			4								2
1300	2.1	2	6.1	6	5	4.2	8	0	<0.1	1	1	8	2
1345	2.1	8	6.2	8	9	4.2	8	0	<0.1	8	1	5	8
AVERAGE VALUE	2.0	3.5	5.4	9	2.7	4.4	8	8	<0.1	8	1	8	1.0

* .45μ MEMBRANE FILTER.

CESIUM 137-BARIUM 137 REMOVAL	
PROCESS	REMOVAL (%)
COAGULATION	0
COAGULATION & DIATOMITE FILTRATION	2.4
COAGULATION & SAND FILTRATION	98.0
COAGULATION, DIATOMITE FILTRATION & CATION EXCHANGE	>99.9
COAGULATION, DIATOMITE FILTRATION, CATION EXCHANGE, ANION EXCHANGE & MIXED BED ION EXCHANGE.	>99.9

Table VI. Run 5 - Decontamination of Well Water Contaminated with Strontium 90-Yttrium 90 by the Mobile Ion Exchange Unit Using Cation Exchange Resin on the Sodium Cycle

	CONTAMINATED WATER								CATION COLUMN EFFLUENT						
SAMPLE TIME	TEMPERATURE (°F)	pH	ALKALINITY (ppm $CaCO_3$)	HARDNESS (ppm $CaCO_3$)	TURBIDITY (UNITS)	COLOR (UNITS)	RADIOACTIVITY (10^3 μμc/l) NO ABSORBER	RADIOACTIVITY (10^3 μμc/l) ABSORBER*	pH	ALKALINITY (ppm $CaCO_3$)	HARDNESS (ppm $CaCO_3$)	TURBIDITY (UNITS)	COLOR (UNITS)	RADIOACTIVITY (10^3 μμc/l) NO ABSORBER	RADIOACTIVITY (10^3 μμc/l) ABSORBER*
PART A															
30 OCT '59															
0900	62	7.8	80	256	40	40	2,050	404	6.6	36	0	16	25	266	104
1000	62	7.7					2,080	416	7.5	76	0			266	104
1100	62	8.1					2,238	462	7.7	76	0			312	104
1200	63	8.1					2,360	508	7.9	76	0			380	115
1300	75	7.9	76	256	40	40	2,220	500	7.8	76	0			520	254
1400	75	8.0					2,370	612	7.8	72	0			427	243
1500	75	8.1					2,150	474	8.0	84	0			300	127
1600	64	8.1					2,090	405	8.2	80	0			558	135
PART B															
2 NOV '59															
0900	58	8.0	90	260	14	5	1,860	520	8.8	78	0			209	127
1000	58	8.0					1,780	500	8.4	87	0			219	92
1100	75	7.9					1,850	485	8.0	87	0			231	81
1200	76	8.1					1,950	580	8.2	87	0			185	81
1300	76	8.0	87			8	1,950	520	8.1	87	0			231	92
1400	76	7.9					1,880	543	8.0	87	0			231	92
1500	76	7.9					1,660	346	8.0	89	0			139	69
1600		7.8					1,660	243	7.9	89	0			185	81
AVERAGE	69	8.3	81	257	31	23	2,010	470	7.9	79	0	16	25	279	119
Sr^{90} ACTIVITY							1107							50	
Y^{90} ACTIVITY							903							229	

NOTE:

* 176 mg/cm²

Y^{90} ACTIVITY = AVERAGE "ABSORBER" ACTIVITY X 1.92

Sr^{90} ACTIVITY = AVERAGE "NO ABSORBER" ACTIVITY MINUS Y^{90} ACTIVITY

RADIOACTIVITY	REMOVAL
STRONTIUM 90	95.5 %
YTTRIUM 90	74.6 %

Table VII. Run 6 - Treatment of Well Water Contaminated with Cesium 137-Barium 137 by an Aquamite-30B Electrodialysis Demineralization Unit

DEMINERALIZATION OF WELL WATER CONTAMINATED WITH CESIUM 137 - BARIUM 137 BY AN AQUAMITE - 30B ELECTRODIALYSIS DEMINERALIZATION UNIT

DATE 1959	CYCLE NUMBER	CONDUCTIVITY SETTING (µmhos/cm)	CONTAMINATED WATER* RADIOACTIVITY (10^3 pc/l)	BRINE STREAM RADIOACTIVITY (10^3 pc/l)	ELECTRODE STREAM RADIOACTIVITY (10^3 pc/l)	PRODUCT WATER RADIOACTIVITY (10^3 pc/l)	PRODUCT WATER TOTAL DISSOLVED SOLIDS (ppm NaCl)	RADIOACTIVITY REMOVAL (%)
28 OCT	1	20	12,600					
	2	20		14,000	12,700	35	4.8	
	3	20	9,600	12,600	12,700	12	3.1	99.7
	4	20		13,200	13,100		3.2	
29 OCT	1	20	12,300	13,000	14,300	12	3.9	99.9
	2	20		12,800	12,700	24	4.8	
	3	20		12,700	12,400	31	5.0	
	4	20		13,000	12,300	12	5.0	
30 OCT	1	20		10,000	9,000	41	3.3	
	2	20	12,100	9,100	9,400	71	4.7	99.4
	3	20		10,800	10,800	41	8.9	
31 OCT	1	20	9,100	8,200	9,200	47	4.8	99.5
	2	20	9,000	9,100	7,000	47	4.0	99.5
	3	20	8,300	8,300	7,600	47	4.8	99.4
2 NOV	1	0	7,700	7,700	7,400	6	1.4	99.9
	2	0	8,300	7,600	7,300	12	1.6	99.9
3 NOV	1	0	6,300	7,100	6,300	12	1.5	99.8
AVERAGE VALUES		20	10,400	11,400	11,100	36	3.2	99.6
		0	7,700	7,500	7,100	10	1.5	99.9

* TOTAL DISSOLVED SOLIDS -987 ppm

TYPICAL CYCLE ANALYSIS

REDUCTION OF TOTAL DISSOLVED SOLIDS AND RADIOACTIVITY ($Cs^{137} - Ba^{137}$) OF WELL WATER BY AN AQUAMITE - 30B ELECTRODIALYSIS DEMINERALIZATION UNIT DURING A TYPICAL CYCLE

CYCLE 4 29 OCT 1959

BRINE STREAM SAMPLE DESIGNATION	BRINE STREAM TIME FROM START OF CYCLE (MINUTES)	BRINE STREAM TOTAL DISSOLVED SOLIDS (ppm NaCl)	BRINE STREAM RADIOACTIVITY (10^3 pc/l)	PRODUCT STREAM SAMPLE DESIGNATION	PRODUCT STREAM TIME FROM START OF CYCLE (MINUTES)	PRODUCT STREAM TOTAL DISSOLVED SOLIDS (ppm NaCl)	PRODUCT STREAM RADIOACTIVITY (10^3 pc/l)
B-B	5	1460	13,700	P-A(FEED)	0	789	12,400
B-C	10	1373	13,200	P-B	5	390	4,100
B-D	20	1293	10,400	P-C	15	320	3,200
B-E	40	1079	14,600	P-D	25	212	1,780
B-F	60	942	13,000	P-E	45	77	340
B-G	80	818	13,230	P-F	60	33	133
B-H	90.7	733	13,100	P-G	86	10	71
B-I	100.4		12,400	P-H	98.7	5	12

RADIOACTIVITY REMOVAL = 99.9%
TOTAL DISSOLVED SOLIDS REMOVAL = 99.4%

APPENDIX E

DOSIMETRY DATA

Table VIII. Field Monitoring of Raw Water

Run No.	Tank No.	Meter Reading (mr/hr)		Contaminant	Water Activity (picocuries per liter)
		In Tank	Background		
1-B	3	0.65	0.2	Bomb debris	900,000
2	4	1.5	0.05	Fused bomb debris	1,600,000
3-A	3	1.35	0.04	Sr^{90}-Y^{90}	1,800,000
4-B	3	7.3	0.03	Cs^{137}-Ba^{137}	13,500,000

NOTE: Radiation readings obtained with Nuclear-Chicago 2612 beta-gamma survey meter. Probe in open position, sheathed with finger of surgeon's glove, and immersed in raw-water tank.

Table IX. Dosimetry Data, Mobile Water Purification Unit

Detector	Run 1 Part B		Run 2		Run 3 Part A		Run 3 Part B		Run 4 Part A		Run 4 Part B	
Exposure time (hr)	5.2	4.5	6.0	6.0	6.0	4.3	6.1	6.1	5.2	5.2	5.8	5.8
Unit of radiation	FB[a] mrem	PD[b] mr	FB mrem	PD mr	FB mrem	PD mr	FB mrem	PD mr	FB mrem	PD mr	FB mrem	PD mr
Position[c]												
1	<10		<10		<10		<10		<10		20	
2	<10		<10		<10		<10		<10		30	
3	<10		<10		<10		<10		<10		50	
4	10		<10		<10		<10		10		60	
5	<10	7	<10	18	<10	9	<10	2	10	55	60	86
6	<10		<10		<10		<10		20		60	
7	10		<10		<10		<10		10		60	
8	<10		<10		<10		<10		<10		50	
9	<10		<10		<10		<10		<10		30	
10	<10		<10		<10		<10		<10		40	
11	<10		<10		<10		<10		<10		40	
12	20	35	90	130	40	50	<10	12	<10	45	50	72
13	<10	0	<10	2	<10	0	<10	6	<10	13	10	10
14	<10	0	<10	7	<10	2	<10	8	<10	12	30	26
15	<10		<10		<10		<10		<10		30	
16	<10		<10		<10		<10		<10		30	
17	<10	9	<10	7	<10	5	<10	5	<10	23	30	37
18	<10		<10		<10		<10		<10		30	

(a) FB Film Badge
(b) PD Pocket Dosimeter
(c) See Fig. 9

Table X. Dosimetry Data, Mobile Ion Exchange Unit

Detector	Run 2		Run 3 Part A		Run 3 Part B		Run 4 Part A		Run 4 Part B		Run 5 Part A		Run 5 Part B	
Detector	FB(a)	PD(b)	FB	PD	FB	PD	FB	PD	FB	PD	FB	PD	FB	PD
Exposure time (hr)	5.3	5.3	5.5	5.5	7.2	7.2	6.2	6.2	6.8	6.8	7.5	7.5	7.5	7.5
Unit of radiation	mrem	mr	mrem	mr	mrem	mr	mrem	mr	mrem	mr	mrem	mr	mrem	mr
Position(c)														
1	<10	5	<10	4	<10	0.5	30	200	100	135	10	8	10	10
2	<10	3	<10	4	<10	0.5	<10	12	40	20	<10		<10	
3	<10	2	<10	2	<10	0.5	<10	1	0	3	<10	0	<10	
4	<10		<10		<10		<10		0		<10		<10	
5	<10		<10		<10		70		290		<10		<10	
6	<10		<10		<10		<10		10		<10		<10	
7	<10		<10	2	<10	0.5	<10		10		10		<10	
8	<10		<10		<10		<10		20		10		10	
9	<10		<10		<10		<10		30		10		<10	
10	<10		<10		<10		<10		40		10		<10	
11	<10		<10		<10		50		110		10		10	
12	<10		<10		<10		330		420		40		10	
13	<10		<10		<10		640		1120		40		30	
14	<10		<10		<10		180		1830		30		50	
15	<10		<10		<10		<10		1000		10		40	
16	<10		<10		<10		<10		120		20		10	
17	<10		<10		<10		<10		20		10		10	
18	<10		<10		<10		<10		10					
19	<10		<10		<10		<10		10					
20	<10		<10		<10		<10		10					
21	<10		<10		<10		<10		<10					
22	<10		<10		<10		<10		<10					
23	<10		<10		<10		<10		<10					
24	<10		<10		<10		<10		10					
25	<10		<10		<10		<10		<10					
26	<10		<10		<10		<10		10					
27	<10		<10		<10		<10		10					
28	<10		<10		<10		<10		10					
29	<10		<10		<10		<10		10					
30	<10		<10		<10		<10		10					
31	<10		<10		<10		<10		10					
32	<10		<10		<10		<10		10					
33	<10		<10		<10		<10		<10					
34	<10		<10		<10		<10		10					
35	<10		<10		<10		<10		10					
36	<10		<10		<10		<10	0	10	7		0		
37	<10		<10		<10		<10		<10		<10	0	<10	7

(a) FB Film Badge
(b) PD Pocket Dosimeter
(c) See Fig. 10

Table XI. Dosimetry Data During Regeneration of Cation Exchange Column[(a)]

NaCl applied (lb)	0		100		200		300		400		500		600	
Survey Meter	T[(b)]	J[(c)]	T	J	T	J	T	J	T	J	T	J	T	J
Position 8	6	8							<1	5	<1	5	<1	5
9	9	12							<1	5	<1	5	<1	5
10	20	20							<1	5	<1	5	<1	5
11	40	42							1	5	<1	5	<1	5
12	85	115							1	8	<1	5	<1	5
13	180	247							3	8	<1	5	<1	5
14	250	355							5	10	<1	5	<1	5
15[(d)]	340	600	180	250	110	175	45	70	11	23	<1	5	<1	5
16	130	250							23	44	1	15	<1	10
17	45	45							46	88	2	45	1	20

(a) Radiation readings (mr/hr) obtained with survey meter on surface of cation column during regeneration, following completion of Run 4, 29 October 1959. Readings taken after passage through the cation column of designated weights of NaCl applied as an 8-percent solution.

(b) Tracerlab No. 1404

(c) Juno SRJ-1

(d) Before start of regeneration, readings on Tracerlab Survey Meter No. 1404 at Position No. 15 were 150 mr/hr at a distance of 6" from surface of cation column, 70 mr/hr at 18", and 28 mr/hr at 36".

Table XII. Dosimetry Data, Electrodialysis Unit
(Film Badge Readings, Run 6)

Location of Film Badge	Exposure Time* (hr)	Dose (mrem)	Dose Rate (mrem/hr)
Top of stack	142.5[(a)]	2900	20.3
Bottom of stack	142.5	2900	20.3
Raw water line	147.3[(b)]	475	3.22
Product recirculation line	147.3	130	0.88
Brine discharge line (pump to unit)	147.3	140	0.95
Brine waste line	147.3	300	2.04
Electrode waste line	147.3	220	1.49
Product discharge line	147.3	110	0.75

* Film badges attached 28 Oct 1959, (a) at 1415 hrs, (b) at 0930 hrs; removed 3 Nov 1959 at 1245 hrs.

Table XIII. Personnel Dosimetry Data

Name	Affiliation	Dosage (mrem)
Beaumont, John S.	USAERDL	0
DesRosiers, Paul E., Jr.	"	10
Feldman, Sidney	"	0
Fox, Harvey	"	10
Gainey, Richard	"	0
Kennedy, Joseph P.	"	210
Lindsten, Don C.	"	330
Mancuso, Joseph F.	"	30
Pressman, Maurice	"	10
Schmitt, Richard P.	"	0
Wolfes, F. W.	"	10
Lewis, Converse R., Jr.	USAMSC	0
Quillin, Robert M.	"	0
Kaplan, Arthur M.	USAQMRDC	20
Goforth, George T.	OCDM	0
Lacy, William J.	"	0
Sieveka, Ernest H.	OSW	0

NOTE: Recorded external radiation exposures derived from film badges issued and processed by the Radiological Safety Division at the Nevada Test Site for personnel accredited to the Engineer Research and Development Laboratories Field Test, September - November 1959.

Category 16 - Water Supply and Sanitation

DISTRIBUTION FOR USAERDL REPORT 1673-RR

TITLE Removal of Nuclear Bomb Debris, Strontium 90-Yttrium 90, and Cesium 137-Barium 137 from Water With Corps of Engineers Mobile Water-Treating Equipment

DATE OF REPORT 23 May 61 PROJECT 8-75-07-460 CLASSIFICATION Uncl.

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DA Proj 8-75-07-460 Unclassified Report

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